The Institution of Gas Engineers

JOURNAL

AUGUST 1961
VOLUME 1 NUMBER 8

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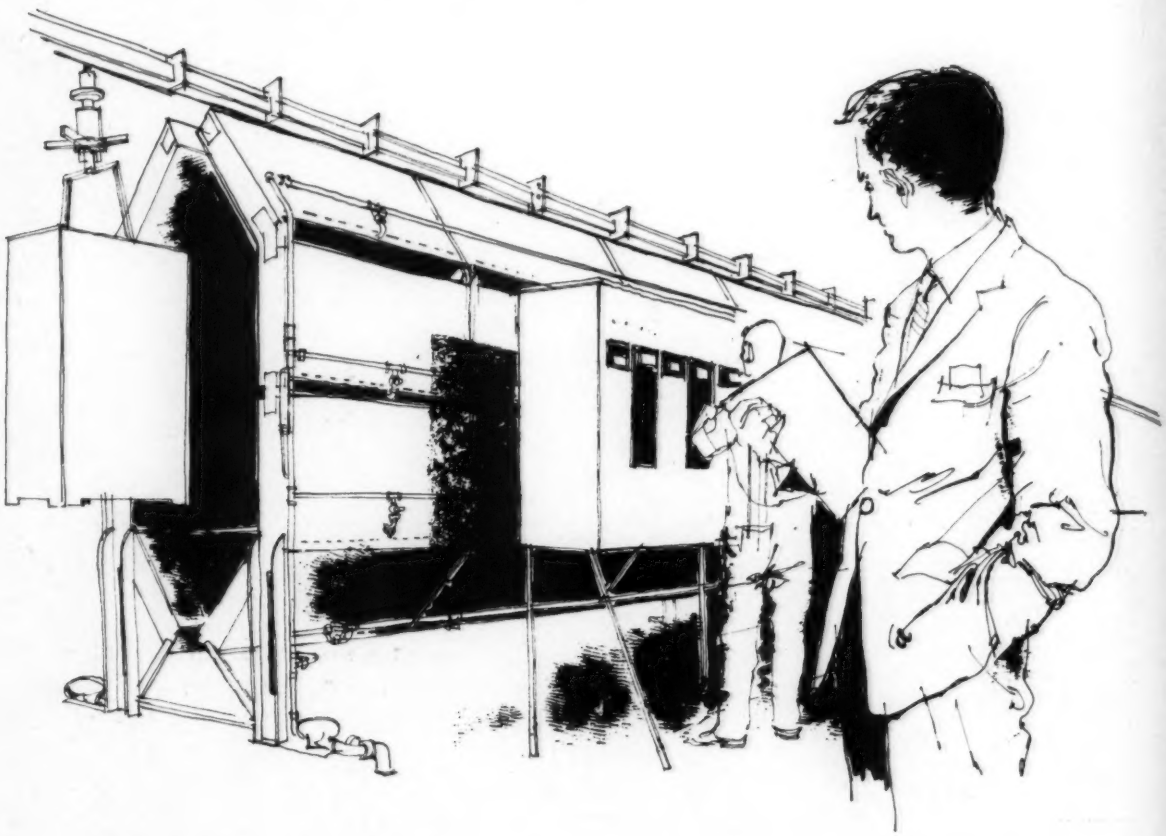

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HYDROGEN SULPHIDE REMOVAL BY THE STRETFORD LIQUID PURIFICATION PROCESS

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COMMUNICATION NO. 593

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I SUMMARY

The Stretford Process is a method of continuous purification of gas or liquid mixtures containing hydrogen sulphide, using an aqueous alkaline solution of the sodium salts of anthraquinone disulphonic acids (A.D.A.), which results in the precipitation of sulphur. The results of batch and dynamic experiments in the laboratory are presented with reference to the effects of reagent concentration, pH, temperature, dissolved oxygen and carbon dioxide removal. Results from a pilot plant and large-scale applications of the process for washing fuel gases are also presented with discussion of costs of operation and side reactions encountered.

A section deals with the use of sodium vanadates with A.D.A. to improve the spread of conversion of hydrogen sulphide to sulphur and to increase the hydrosulphide loading of the washing medium.

The results obtained in the laboratory and on the plant demonstrate that the Stretford Process is a successful and economic method of removal of hydrogen sulphide from gas streams.

II INTRODUCTION

The Stretford Process, developed jointly by the North Western Gas Board and The Clayton Anilline Company, Limited. was intended initially for the removal of hydrogen sulphide from coal gas. Subsequent work, however, has shown that the process is suitable for the removal of hydrogen sulphide from gas streams of various composition and from solvents immiscible with water.

The need for a continuous liquid purification system for the removal of hydrogen sulphide from coal gas is one that is generally accepted and which is daily becoming more acute. The problems associated with dry box purification are numerous and well-known. In addition to labour difficulties, large ground space requirements, dust hazards, *etc.*, can now be added the difficulty of disposal of spent oxide as a result of the ready availability of pure sulphur on a large scale.

Many liquid purification systems have been described in the technical literature, and a number are in commercial operation. Processes favoured in the oil and kindred industries make use of absorption/desorption of hydrogen sulphide, the desorbed hydrogen sulphide usually being fed to a Claus kiln. Such processes include the ethanolamine process[1]; the Seaboard process[2]; and the Vacuum carbonate process[3]. These systems often employ corrosive reagents requiring specialized plant; moreover, the hydrogen sulphide requires a secondary treatment for conversion to sulphur. Processes that have found most favour in the gas industry rely on the overall oxidation of hydrogen sulphide to sulphur, as does the present process; hitherto, however, one or more difficulties have usually arisen. Systems have been described that employ iron oxide suspensions in alkali. These have followed on logically from oxide box purification and include the Manchester Process, which has been the subject of papers presented to The Institution of Gas Engineers[4, 5] and the related Ferrox Process[6], in both of which the alkali used is sodium carbonate, and the Gluud Process[7], in which ammonium carbonate is used as alkali. The principal disadvantages with these processes are the high power costs needed to circulate the heavy suspension of iron oxide and to provide air to re-oxidize it, the quality of the sulphur obtained, and the occurrence of side reactions. Other processes use solutions rather than suspensions and thus commend themselves by virtues of lower pumping costs. The Giammarco-Vetrocoke[8] and Thylox[9, 10] processes employ alkaline solutions of thioarsenate, reduced by hydrogen sulphide to thioarsenite which is re-oxidized by air with precipitation of sulphur. There is a reluctance to use arsenical compounds, which result in contamination of the recovered sulphur.

Following the First World War, the South Metropolitan Gas Company became interested in finding a market for dyestuffs produced at its tar works, and in 1921 patented[11] a process, for the removal of hydrogen sulphide from coal gas, which utilized indigo carmine and like compounds. More recently, the South Eastern Gas Board introduced the Seblu process[12], which used methylene blue in the oxidation-reduction system. The difficulty here lay in the tendency for demethylation of the reagent, rendering it insoluble in the organic solvents used in the process, and in the subsequent removal of the sulphur.

The Stretford Process uses an alkaline solution of the sodium salts of anthraquinone 2:6, 2:7 disulphonic acids, which are water-soluble and non-toxic. They are also highly stable chemicals, and certainly not decomposed in the conditions found in this process. The advantages over the Thylox and Ferrox processes can thus be seen. It is also possible with this process to control side reactions to defined limits.

The process is considered to take place in five stages:—

(1) Absorption of hydrogen sulphide in alkali.
(2) Reduction of the anthraquinone disulphonic acid by means of addition of sulphur (in the form of hydrosulphide) to a carbonyl group.
(3) Liberation of sulphur from the reduced anthraquinone disulphonic acid by interaction with oxygen dissolved in the water.
(4) Re-oxidation of the reduced anthraquinone disulphonic acid.
(5) Re-oxygenation of the alkaline solution providing dissolved oxygen in the solution for stage 3 of the process.

The process is normally operated in the pH range 8·5 to 9·5, and for many applications a more restricted range of 8·8 to 9·1 is preferred. In these ranges, absorption of hydrogen sulphide results in hydrosulphide rather than sulphide ions which is a necessary condition of the process. The required pH is obtained by using sodium carbonate and sodium bicarbonate in the ratio 1:3, but ammonium salts or other alkaline salts can also be used. The commercial mixture of anthraquinone disulphonic acids (sodium salts) normally employed consists of almost equal amounts of the 2:6 and 2:7 isomers. It is equally possible to use other anthraquinone disulphonic acid isomers, notably a mixture of anthraquinone 1:5 and 1:8 disulphonic acids (sodium salts), but on price considerations, speed of reduction and general convenience in the precipitation of sulphur it is preferred to use the 2:6, 2:7 isomers. Theoretical considerations of hydrogen sulphide absorption and a proposed reaction mechanism are discussed in a later section.

In addition to the removal of hydrogen sulphide from coal gas, the process has also been tested for application to the purification of refinery gases, effluent air streams such as those encountered in the viscose and transparent paper industries, gases rich in carbon dioxide and also for the purification of crude benzoles and petroleum products containing hydrogen sulphide. These applications and the addition of vanadates to the process to increase the speed of the reduction reaction are discussed later.

III REACTION MECHANISM

The overall reaction in this process involves the oxidation of hydrogen sulphide, making use of oxygen from the air to produce sulphur:—

$$H_2S + \tfrac{1}{2} O_2 \longrightarrow S + H_2O.$$

However, some of the intermediate reactions are comparatively slow and the rate of absorption of hydrogen sulphide from a gas mixture by the buffered alkaline solution in the range 0° to 30°C depends entirely upon the pH of the solution.

The hydrogen sulphide dissolves in the liquor and undergoes partial dissociation to give the equilibrium represented as under:—

$$\underset{\text{Gas Phase}}{H_2S} \rightleftharpoons \underset{\text{Liquid Phase}}{H_2S} \rightleftharpoons H^+ + HS^-$$

At equilibrium, the hydrogen sulphide concentration in the gaseous phase is proportional to the concentration of non-ionized hydrogen sulphide in the liquid phase, which is itself in equilibrium with the H^+ and SH^- ions. Thus the concentration of non-ionized hydrogen sulphide in solu-

tion, which controls the equilibrium vapour pressure above the liquid, is only a fraction of the total sulphide content of the solution. The dissociation constant of hydrogen sulphide is $0{\cdot}91 \times 10^{-7}$ at 25°C; this implies that, at a pH value of 9, approximately 1 per cent of the sulphide in solution would be non-ionized. Assuming Henry's Law is applicable, and that the activity of non-ionized hydrogen sulphide is the same in a solution of pH9 as it would be in water, the equilibrium vapour pressures may be calculated. Calculations for other temperatures and pH values may also be made.

Further ionization to give the sulphide ion $S^{=}$ according to the equilibrium:—

$$HS^{-} \rightleftharpoons H^{+} + S^{=}$$

does not occur to any appreciable extent until the pH of the solution exceeds a value of 12, since the dissociation constant is 1×10^{-15} at 25°C.

Having obtained the solution of hydrosulphide, an addition compound with A.D.A. is formed, which, in the presence of oxygen in solution in the liquor, will liberate sulphur and leave a reduced form of the anthraquinone disulphonic acid. Finally, oxidation by blowing air through the reduced solution will regenerate the original reagent and also reoxygenate the liquor.

The following equations represent a proposed reaction scheme that conforms with the available experimental evidence.

(1) $2Na_2CO_3 + 2H_2S \rightleftharpoons 2NaHS + 2NaHCO_3$

(2) $2RC{=}O + 2NaHS \rightleftharpoons 2RC\begin{<}{ONa \\ SH}$

(3) $2RC\begin{<}{ONa \\ SH} + \tfrac{1}{2}O_2 \longrightarrow RC{=}O + RC\begin{<}{ONa \\ H}$
(dissolved oxygen) $+ 2S + NaOH$

$NaHCO_3 + NaOH \longrightarrow Na_2CO_3 + H_2O$

(4) $RC\begin{<}{ONa \\ H} + \tfrac{1}{2}O_2 \longrightarrow RC = O + NaOH$
(air oxidation)

$NaHCO_3 + NaOH \longrightarrow Na_2CO_3 + H_2O$

Several intermediate complexes have been postulated giving rise to both oxanthrol and the anthrahydroquinone forms of the reduced reagent, but the structure of such intermediate compounds has not been established. However, in batch experiments in the laboratory it was found that two sulphur atoms were liberated for each atom of oxygen in solution in the washing medium, that no alkali was consumed unless some side reaction producing thiosulphate occurred, and that the anthraquinone disulphonic acid could be regenerated in full. The amount of oxygen dissolved in the washing medium depends upon the temperature, pressure and degree of saturation achieved in the oxidizer. At 20°C and normal atmospheric pressure saturation occurs at 9 p.p.m., which is equivalent to 38 p.p.m. of hydrogen sulphide. Thus the oxygen content of the liquor sets the limit for the sulphide loading if a complete precipitation of sulphur is to be achieved before the washing medium is pumped to the oxidizer. Should there be no dissolved oxygen available to carry out reaction 3, then reaction 2 proceeds slowly to an equilibrium with the normal change in colour of the solution to deep red, but no sulphur can be precipitated until the liquor reaches the oxidizer.

Since most of the experimental work has been carried out on the removal of hydrogen sulphide from fuel gases in which carbon dioxide has been present in differing amounts, some attention has been paid to selective absorption of hydrogen sulphide.

The dissociation constant for carbon dioxide is approximately 4×10^{-7} at 25°C, compared with $0{\cdot}9 \times 10^{-7}$ for hydrogen sulphide; however, hydrogen sulphide is absorbed more rapidly into alkaline solution because ionization occurs immediately on solution, whereas the carbon dioxide must first react with water to give carbonic acid and then ionize to H^{+} and HCO_3^{-}. Solution of carbon dioxide is thus restricted by the slow chemical reaction. In practice, it is usually desirable to remove as much hydrogen sulphide and as little carbon dioxide as possible to keep the cost of decarbonation of the washing medium to a minimum. Carbon dioxide removal is considered a typical liquid film controlled process, not because its gas film resistance is less than that of hydrogen sulphide, but because its liquid film resistance is so much greater. Both liquid and gas film resistances are important in the absorption of hydrogen sulphide, but, with an adequate excess of alkali and suitable pH and not more than one per cent of hydrogen sulphide in the gas stream, it is controlled mostly by the gas film resistance.

That the selectivity of washing is influenced by the method of contact of gas and liquid was demonstrated by Eymann[13] and Bahr[14], who measured the rates of solution of hydrogen sulphide and carbon dioxide in dilute alkali with quiescent surfaces at 1 atmosphere pressure and room temperature. Hydrogen sulphide dissolved twice as fast as carbon dioxide. Eymann showed experimentally that, if the gases were absorbed by falling drops of the same alkaline liquor under the same conditions of temperature and pressure, hydrogen sulphide dissolved 85 times as fast as carbon dioxide. Repeating this falling-drops experiment at 21°C, with a coke oven gas containing 2 per cent of carbon dioxide and 0·5 per cent of hydrogen sulphide, Eymann found the solution of hydrogen sulphide was 17 times faster than carbon dioxide. Bahr has reported a mole ratio of hydrogen sulphide to carbon dioxide of 10:1 and Bayerlein[15], on a first-stage water washing of coal gas at temperatures between 65°F and 77°F, has reported mole ratios of 6·3:1.

The results of Mai and Babb[16], using sodium salts, and Dryden[17], using potassium salts, are useful as basic design information on the washing of gas mixtures with alkaline solutions.

More recently, in a survey of selective absorption of hydrogen sulphide and carbon dioxide in carbonate solutions, Garner, Long and Pennell[18] have detailed the following conditions, which will provide efficient operation. The operating temperature should be as low as it is practicable and the carbonate-bicarbonate solution as strong as bicarbonate solubility will permit; the contact time between gas and liquor should be short and the absorption towers operated with a high gas velocity and low liquid flow.

Since some carbon dioxide is always removed by the alkaline solutions, there is a continuous conversion of sodium carbonate to sodium bicarbonate until, eventually, the carbon dioxide removed from the fuel gas is equalled by the carbon dioxide lost in the air blown through the oxidizers. At the temperatures of normal operation, most of the carbonate would be converted to bicarbonate and pH of the washing medium would have fallen below the level required for the economic removal of hydrogen sulphide from the gas stream. Thus some form of decarbonation of the washing medium is required. In practice, about 1 per cent of the circulating liquor has been heated to about 90°C in a heat exchanger and then allowed to flow down a packed column up which hot air or steam or both

have been blown. Carbon dioxide is released from the solution and carried away by the gases passing up the tower. The effluent liquor has a high carbonate to bicarbonate ratio and is hot, so must be cooled before being returned to the circulating liquor. In theory, the overall process produces water, but it has been found that the loss of water from the decarbonator exceeds the amount of water produced in the reaction.

In a washing solution containing 0·5 per cent of the commercial mixture of anthraquinone 2:6, 2:7 disulphonic acids (A.D.A.) in the pH range 8·5 to 9·5 and a hydrosulphide loading of 40 p.p.m., the time required to reach a sulphide-free condition is of the order of 20 min. Providing there is free access of air to the surface of the liquor, the time required is less than when the solutions are sealed. The liquor surface must be exposed to air when greater hydrosulphide loadings are to be used. The concentration of A.D.A. in solutions with hydrosulphide contents between 20 and 100 p.p.m. is of little importance. 0·5 per cent A.D.A. is a large excess and, unless the concentration falls below 0·2 per cent, there is little change in reaction rates with A.D.A. concentration.

Compared with the reduction stage, oxidation of the reduced anthraquinone disulphonic acids is rapid, so rapid over the pH range of normal operation that attempts to determine oxidation rates in the laboratory have been unsuccessful. The time taken for oxidation was controlled by the rate of solution of oxygen in the liquor. In practice, there has often been some hydrosulphide and intermediate compound in the liquor fed to the oxidizers, sometimes because the reaction tank baffles have not been effective in ensuring adequate residence time, and also because the theoretical loading of 40 p.p.m. hydrosulphide in solution has been exceeded in order to clean more gas for a given liquor circulation at the expense of some side reaction products being formed. The presence of other sources of oxygen in solution, such as hydrogen peroxide and polythionates, can assist in the conversion of hydrogen sulphide to sulphur. Since reaction 2 is a presumed equilibrium, the greater the amount of hydrosulphide the greater the amount of the intermediate compound. This intermediate compound will react with oxygen in the oxidizer in the same manner as it does with dissolved oxygen, except that there must always be some free hydrosulphide ions in the equilibrium, which may be oxidized directly to thiosulphate. The oxidizer has, therefore, the twin rôle of completing the oxidation of the hydrosulphide and intermediate compounds and re-oxidizing the reduced reagent. Co-current oxidation, air and liquor fed together at the bottom of the oxidizer is necessary in order to prevent the contamination of the effluent air with hydrogen sulphide. Along with the re-oxidation of the reagent there is re-oxygenation of the washing liquor, which is necessary before the liquor can be recycled. Theoretically, the highest possible degree of re-oxygenation is achieved in a counter-current system, but only single co-current oxidizers have been used in practice.

IV EXPERIMENTAL

(A) Laboratory Batch

The reactions taking place when solutions of sodium salts of anthraquinone disulphonic acids are mixed with alkaline solutions of hydrosulphide have been followed in batch systems in the laboratory. The reactions were carried out in 1 litre vessels that had an atmosphere of air or nitrogen above the solutions; provision was made to stir the liquor and to remove samples for analysis at 2-min intervals. The sulphide content of the liquor sample was determined by precipitation as zinc sulphide by the addition of zinc chloride in ammonium chloride solution; the precipitate was filtered, washed and dropped into an iodine solution containing hydrochloric acid. Hydrogen sulphide released reacted with some of the iodine, and the excess iodine was determined by titration with a standard thiosulphate solution.

It was found that the rate of change of the hydrosulphide concentration decreased with a rise in the pH over the range 8·5 to 9·5, as shown in Figure 1. The hydrosulphide loading was 120 p.p.m. At pH levels above 9·5, the reaction rates are so slow as to be unsuitable for large-scale operation. Although the solutions became dark red, indicating that reactions 2 and 3 were progressing with very slow precipitation of sulphur, it was not possible to achieve satisfactory oxidation. Figure 2 shows the variation of reaction rate with changes in temperature; however, it has been found that side reactions producing thiosulphate are accelerated by the higher temperatures, and very little work has been carried out above 40°C.

Figures 3 and 4 show optical densities in arbitrary units from the examination of solutions in the ultra-violet spectrometer, and in effect show the reaction rates of reaction 2 producing the coloured complex with the four isomers in Figure 3 and with the 2:6 isomer at a range of pH levels in Figure 4. From Figure 3, it may be seen that the 2:6 and 2:7 isomers are more satisfactory in their behaviour than 1:5 or 1:8.

If the reactions were carried out in the presence of air, the solutions eventually became sulphide-free even though there may have been 100 p.p.m. hydrosulphide in solution. However, if the solutions were mixed under an atmosphere of nitrogen, there was a change in colour as normally takes place with reaction 2, but no sulphur was formed and there was no change in the sulphide concentration in solution as determined by the above method. With the addition of water that had previously been boiled and allowed to cool under an atmosphere of nitrogen, there was no change in the sulphide content of the solution. However, when aerated water was added, the reaction proceeded with the precipitation of sulphur until no more oxygen remained in solution or all the hydrosulphide had reacted. By determination of the oxygen dissolved in the water added, and the change in sulphide concentration in the solution, a relationship has been established which indicates that 1 atom of oxygen is equivalent to 2 atoms of sulphur. Hence, equation 3 of the reaction mechanism. Thus, when the washing medium is saturated with oxygen from the air, it will contain 9 p.p.m. oxygen, which is equivalent to 38 p.p.m. hydrogen sulphide in solution, and if the liquor is to be fed to the oxidizer in a hydrosulphide-free condition the limit of sulphide loading is approximately 40 p.p.m. in solution. Should the liquor fed to the oxidizer contain some hydrosulphide or intermediate compound, then a proportion of the sulphur combined in this form will be converted to thiosulphate, the proportion depending upon the pH and temperature of the liquor.

(B) Laboratory Dynamic

Dynamic experiments were carried out in the laboratory to determine the effect of a number of variables encountered in the Stretford process. The apparatus was designed to give a contact time of gas in the washing towers, liquor in reaction tank and oxidizer, and gas and liquor flow rates comparable with a large-scale plant.

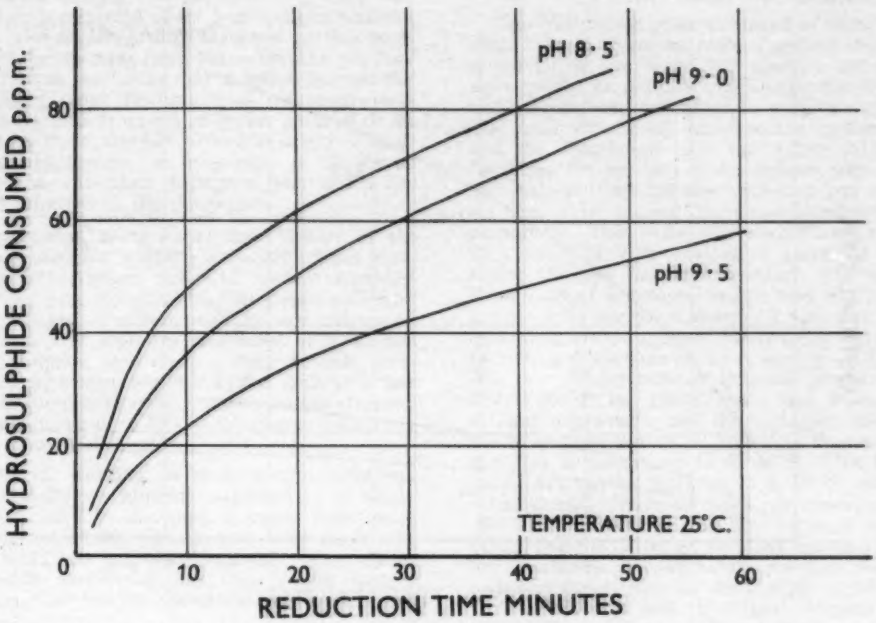

FIGURE 1.—*Effect of* pH *upon Rate of Reduction.*

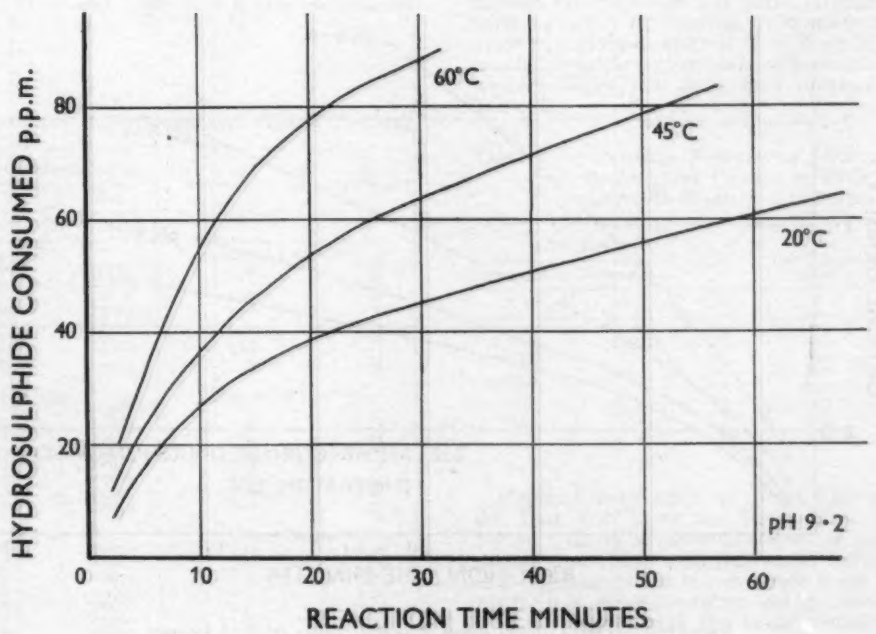

FIGURE 2.—*Effect of Temperature upon Rate of Reduction.*

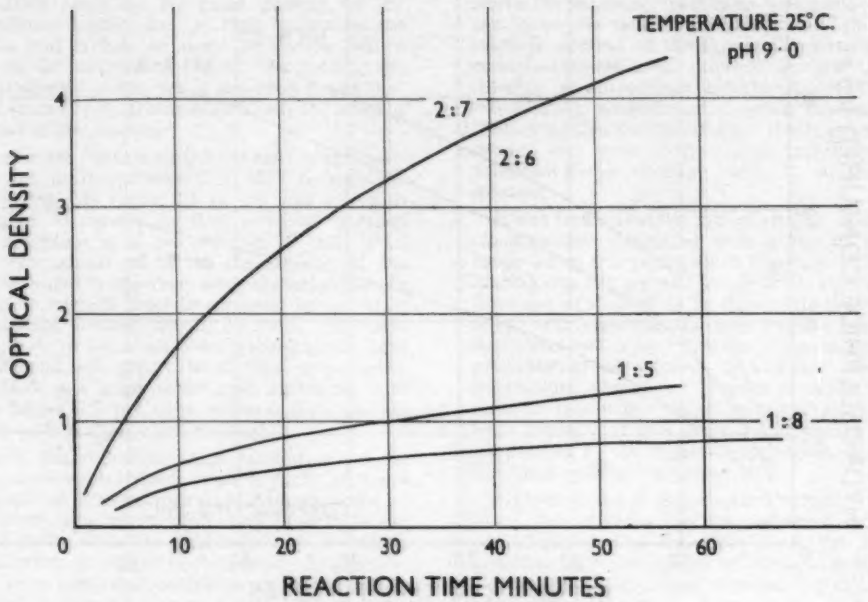

FIGURE 3.—*Reaction Rates of A.D.A. Isomers.*

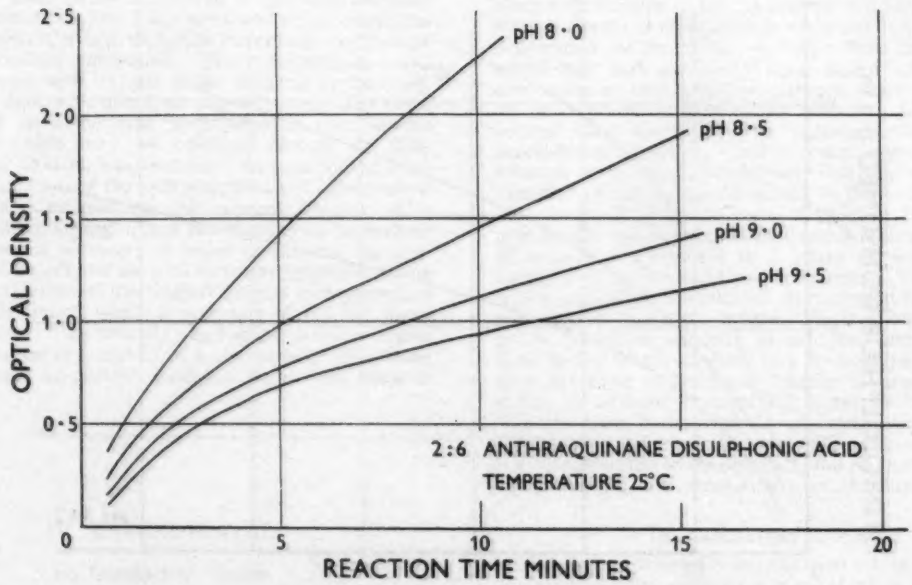

FIGURE 4.—*Effect of* pH *upon Reaction Rates of 2 : 6 Isomer.*

The apparatus for washing coal gas containing 1 per cent of hydrogen sulphide consisted of six 2-in diameter washing towers, packed with Raschig rings arranged so that each tower was fed at the top with clean liquor and the gas flow was countercurrent to the liquor and in series through the towers. The liquor from the bottom of the towers was collected in a delay tank from which it was pumped to an oxidizer and from there allowed to overflow into a tank that fed the washing towers. A proportion of the liquor from this feed tank was taken through a filter and a decarbonator and returned to the delay tank.

This basic apparatus, using either three towers or six towers, has been used for washing a variety of gas mixtures including air/hydrogen sulphide, carbon dioxide/hydrogen sulphide, propane/propylene/hydrogen sulphide. This apparatus was preceded by a single flooded column of 3-in diameter and 3 ft high for treatment of a 40 per cent hydrogen sulphide in air, or a light benzole containing dissolved hydrogen sulphide. The apparatus has been operated at room temperature with most gas streams, but also at temperatures up to 78°C with streams containing large amounts of carbon dioxide.

The apparatus for washing air streams containing less than 50 p.p.m. hydrogen sulphide consisted of a single ring-packed tower of 2-in diameter, a pump and liquor feed tank. The delay tank and oxidizer were no longer necessary for these low sulphide loadings. For higher hydrogen sulphide loadings it has been found that a separate oxidizer restricts the formation of thiosulphate.

Provided the column packing is fully wetted, the irrigation rate has little influence upon the weight of sulphide removed from the gas stream. However, pH has a considerable effect upon the percentage removal of hydrogen sulphide in a given column, as also does the wetted surface presented to the gas stream.

Table 1 gives data for a laboratory column of 2-in diameter and 2 ft packed depth with a coal gas velocity (empty tower) of 0·2 ft/s.

TABLE 1.—*Laboratory Experiments with Packed Columns.*

pH	Partial Pressure H_2S at.		Mass Transfer Coeff. (lb moles/ft³ h. at.)	K (lb/ft³ h. at.)
	In	Out		
1	2	3	4	5
Wood packing 30 ft²/ft³			Irrigation 150 gal/ft²/h	
8·5	0·1	0·0050	0·93	1·05
8·6	0·1	0·0043	1·13	1·27
8·7	0·1	0·0036	1·35	1·52
8·8	0·1	0·0030	1·59	1·79
8·9	0·1	0·0027	1·72	1·93
9·0	0·1	0·0025	1·85	2·08
9·1	0·1	0·0022	1·98	2·23
9·2	0·1	0·0020	2·12	2·38
Wood packing 45 ft²/ft³			Irrigation 300 gal/ft²/h	
8·5	0·1	0·0029	1·65	1·24
8·6	0·1	0·0026	1·79	1·34
8·7	0·1	0·0023	1·96	1·47
8·8	0·1	0·0020	2·12	1·59
8·9	0·1	0·0017	2·32	1·74
9·0	0·1	0·0014	2·55	1·91
9·1	0·1	0·0012	2·82	2·11
9·2	0·1	0·0010	3·13	2·35
Ring packing 90 ft²/ft³			Irrigation 300 gal/ft²/h	
8·5	0·1	0·0014	2·55	0·96
8·6	0·1	0·0012	2·82	1·06
8·7	0·1	0·0010	3·57	1·34
8·8	0·1	0·00075	4·2	1·57
8·9	0·1	0·0005	4·9	1·84
9·0	0·1	0·0004	5·3	1·99
9·1	0·1	0·0003	5·7	2·14
9·2	0·1	0·0002	6·1	2·29

(c) Plant Operation: Whitchurch

The Whitchurch plant consisted of three washing towers each 2 ft in diameter with a packed depth of 10 ft of board filling ¼-in board ¼-in space, a delay tank of 1,000 gal capacity, an oxidizer of 670 gal capacity, a decarbonator and a high-speed centrifuge to remove suspended sulphur. The total volume of liquor in the system was 1,500 gal and the circulation rate was 1,500 gal/h. The liquor contained 0·5 per cent of the sodium salts of 2:6 and 2:7 anthraquinone disulphonic acids and 0·4N total alkali made up from 0·1N sodium carbonate and 0·3N sodium bicarbonate. This ratio was maintained, keeping the pH at a value of 9 by passing 7 gal/h of the circulating liquor through the decarbonator. The gas stream was from a set of horizontal retorts and was purified in oxide boxes in the normal manner. It was then passed through a catalyst bed to convert the organic sulphur compounds to hydrogen sulphide giving a loading of 30 to 40 gr/H_2S/100 ft³. Whitchurch is a small works making about 250,00 ft³/d; the whole make goes through the organic sulphur convertors, and the hydrogen sulphide produced has been removed by a Stretford Process liquid purifier designed to remove up to 50 gr/H_2S/100 ft³ of gas. The plant was put to work in May, 1959, and has operated satisfactorily. With an inlet gas containing 35 gr/H_2S/100 ft³, the outlet of the first tower is normally 1 or 2 p.p.m. and the outlet of the plant less than 0·1 p.p.m. During 18 months of continuous operation, this plant has had technical supervision for the first six months only, and has purified over 100 mill/ft³ of gas. During this period, the thiosulphate content of the solution has reached 2·5 per cent and thiocyanate 1 per cent; 80 lb of A.D.A. and 4 cwt of sodium carbonate have been added. Over 3 tons of sulphur have been removed by the centrifuge, which was operated for 10 h/week.

By using a bypass line, it is possible to feed gas from the oxide boxes direct to the first washing tower, then through the convertors and finally through the second and third washers. By slipping hydrogen sulphide from the oxide boxes to the extent of 50 to 80 gr/H_2S/100 ft³, some results for percentage removal of hydrogen sulphide by the washing liquor that have been obtained are shown in Table 2.

TABLE 2.—*Percentage Removal of Hydrogen Sulphide by the Stretford Process at Whitchurch Works of the North Western Gas Board.*

H_2S First Bay		pH	Gas Velocity (ft/s)	Mass Transfer Coeff. (lb moles/ft³ h/at.)
In (p.p.m.)	Out (p.p.m.)			
1	2	3	4	5
1,300	16	9·0	0·83	4·25
1,000	8	9·0	0·90	4·50
1,000	10	9·0	0·83	4·23
1,000	10	9·0	0·78	4·05
700	5	9·0	0·76	4·13
800	7	8·9	0·74	3·93
800	5	8·9	0·70	3·74
800	3	8·9	0·69	3·74
800	30	8·8	0·70	2·69

Figures 5 and 6 are views of the Whitchurch plant from the East and from the South West respectively. In Figure 5, the three left-hand towers are part of the organic sulphur conversion unit, the central tower is the oxidizer, and the three darker towers beside it are the gas washers. Figure 6 shows the oxidizer and gas washers at the rear, with the reaction tank and liquor circulating pump in the lower foreground, and the centrifuge on the platform to the left.

All the vessels and pipework are of mild steel, and no evidence of corrosion has been found in either washing towers or oxidizer. However, some corrosion has taken place at the bottom of the reaction tank, where an accumulation of sulphur, settling out of the washing liquor, has occurred. The reaction tank has been modified to prevent this sedimentation of sulphur in future.

(D) Plant Operation: Rochdale Road, Manchester

The plant at Rochdale Road was built originally for, and operated on, the Manchester Process. It consisted of six washing bays packed with board filling ½-in board and ½-in space, a delay tank, an oxidizer and a plate and frame filter. There were 40,000 gal of washing liquor in the system for a circulation rate of 40,000 gal/h. The plant was put to work in May, 1959, and ran until December, 1959, when it was decided that the design of the plant was unsuitable and the cost of alteration excessively high. It was decided, instead, to make alterations to another Manchester Process plant at Linacre, Liverpool, and continue the investigations there. At Rochdale Road, the reaction tank was too small and the oxidizer was larger than necessary. The method of air injection through cloth sleeves at the end of a series of tubes was not satisfactory in that the sulphur formed blocked the cloth sleeves. The plate and frame filter was too small and required too many man hours to operate. The liquor distributors on the washing bays were badly located and lacked cleaning facilities. At Rochdale Road, it was found out what to avoid, and these lessons were applied successfully in the conversion of the Linacre plant.

However, the Rochdale Road plant operated for six months on a throughput of 2 mill. ft^3/day of a continuous vertical retort gas containing 600 gr/H_2S/100 ft^3. Some results are given in Table 3 for the percentage removal of hydrogen sulphide by the first bay when operating with an irrigation rate of 300 gal/ft^2/h. The results are collected from routine tests over a period of two months, and variations, due to uneven liquor distribution, are to be expected. Data regarding running costs were also collected and are reviewed in Section V.

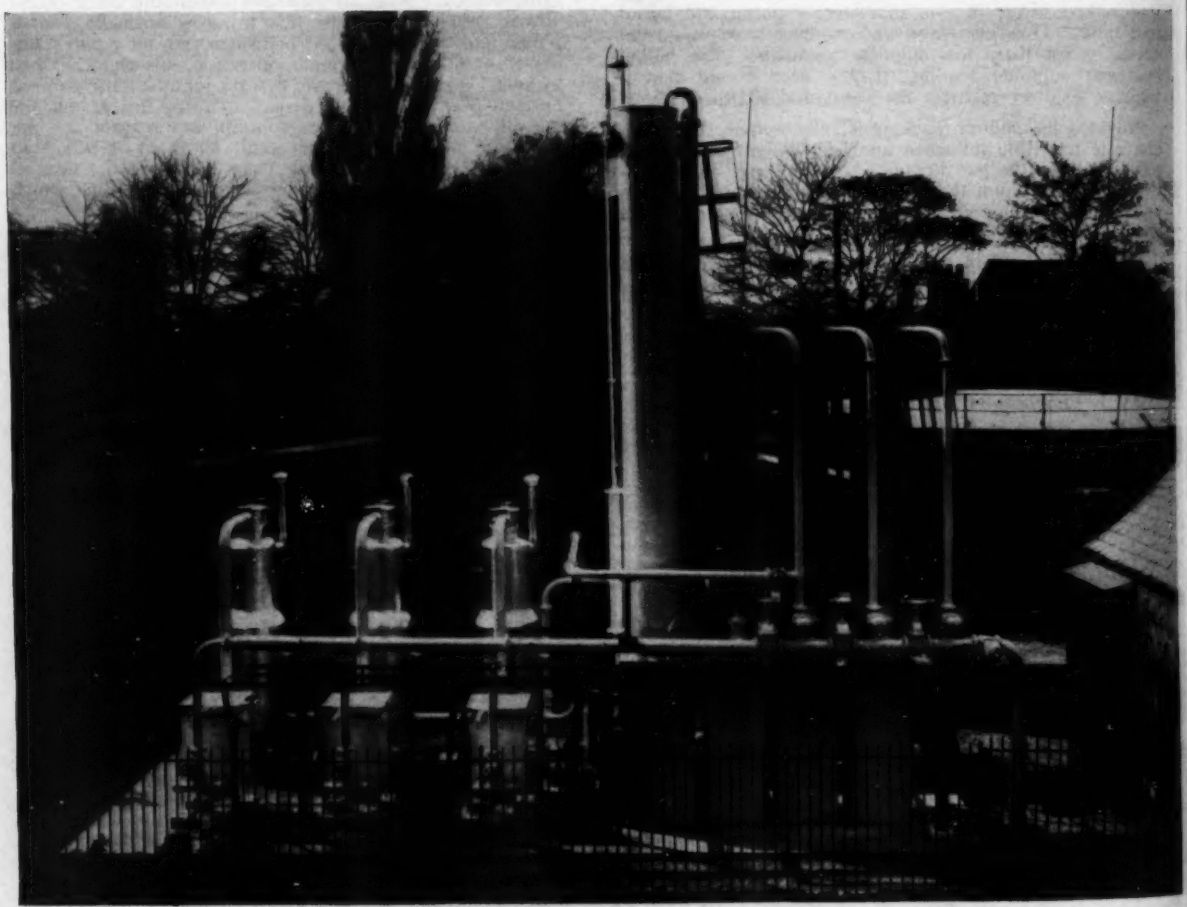

Figure 5.—*View of Plant at Whitchurch.*

FIGURE 6.—*View of Plant at Whitchurch.*

TABLE 3.—*Percentage Removal of Hydrogen Sulphide by the Stretford Process at Rochdale Road Plant of the North Western Gas Board.*

pH	Gas Velocity ft/s (empty tower)	Percentage H_2S Removed	Mass Transfer Coefficient (lb moles/ft³h/at.)
1	2	3	4
8·8	0·59	91	0·59
	0·62	90	0·70
	0·67	89	0·77
	0·83	86	0·93
	1·4	65	0·81
	1·7	47	0·66
	1·8	45	0·59
	1·8	40	0·51
8·9	1·3	62	0·75
	1·3	65	0·88
	1·4	67	0·88
	1·4	67	0·84
	1·5	60	0·96
	1·5	67	0·74
	1·7	65	0·96
	1·7	60	0·88
9·0	1·3	77	1·14
	1·4	75	1·10
	1·5	72	1·21
	1·7	74	1·25
	1·7	68	1·18
	1·8	68	1·18
	2·0	65	1·10
9·1	1·1	90	1·33
	1·2	85	1·25
	1·3	80	1·25
	1·4	80	1·25
	1·5	77	1·40
	2·0	70	1·25

(E) PLANT OPERATION: LINACRE, LIVERPOOL

The plant is basically the same as that designed for the Manchester Process,[4] although much of the ancillary plant has been altered to suit the Stretford Process. (Figure 7.)

There were six washers, 7 ft 6 in by 25 ft overall height, the packed depth being 15 ft. The tower filling consisted of ½ in × ½ in wooden grids. Liquor flow to the washers was parallel flow, i.e., clean liquor from the oxidizers was fed to each washer separately.

There were four reaction tanks, the first two being original equipment for the Manchester Process operation. These tanks were 9 ft in diameter and 25 ft high, and were fed with foul liquor that was pumped from the two foul-liquor pumping legs, situated between the washers, into the top of the tanks. From these primary reaction tanks (1) and (2), liquor flowed from a conical base and up to a 20 ft high manifold main feeding the secondary reaction tanks (3) and (4). These vessels were originally oxidizers, the connexions having been altered to provide more reaction time than was necessary for the Manchester Process. These reaction tanks were 10 ft in diameter and 25 ft high, but the liquor depth was approximately 17 ft, due to the space at the base allowed for the air inlets. Liquor flow to these reaction tanks was by gravity feed from the primary tanks, the inlets being at the top and the outlets at the base, feeding direct to the base of the oxidizers.

The two oxidizers were 10 ft in diameter and 25 ft high, but the actual depth of liquor was about 17 ft. Liquor

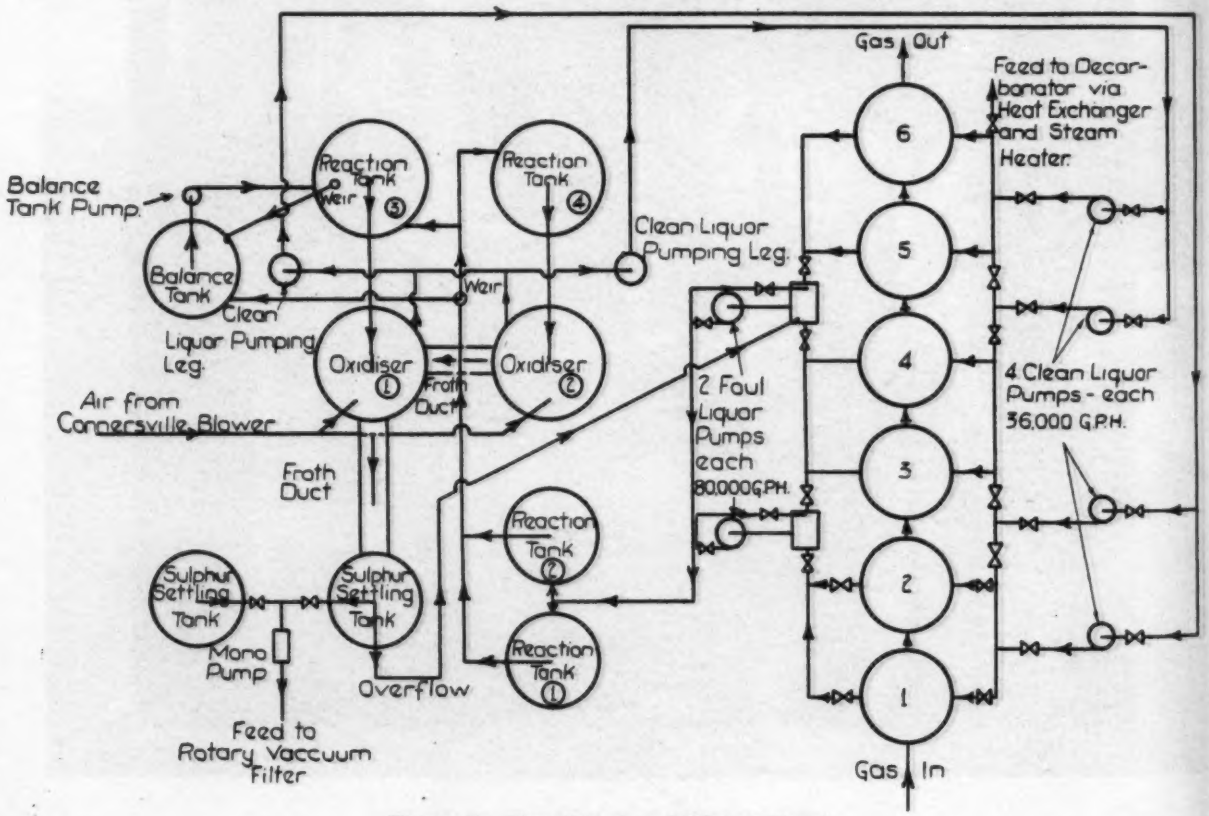

FIGURE 7.—*Flow Diagram of Plant at Linacre.*

overflowed from the oxidizers into the clean-liquor pumping legs, which were kept flooded by maintaining a high level in the secondary reaction tanks. This was achieved by an overflow system into the balance tanks, and effectively maintained the level in the oxidizers as these are gravity-fed from reaction tanks (3) and (4).

Each oxidizer was fitted with three motor-driven rotating hoods or "spinners" in which the air from the Connersville blower was sheared into fine bubbles. The froth created rose to the surface of the liquor and overflowed, *via* froth ducts, to the sulphur-settling tanks. The froth was rich in sulphur, which settled to the conical base of the settling tanks, from where it was pumped to the rotary vacuum filter.

A small portion of clean liquor was taken from the manifold feeding liquor to the washers, and pumped, *via* heat exchangers and a steam heater, to the decarbonator, which handled up to 1,200 gal/h.

The liquor in the whole system was 60,000 gal of a similar composition to the liquor at Whitchurch, and the circulation rate was 100,000 gal/h. The gas being purified was a primary flash distillate-enriched water gas containing approximately 250 gr/H_2S/100 ft³. The plant was put to work in June, 1960, and has operated at throughputs of 6 mill. ft³/d of gas.

In Table 4 are given some of the data collected during August and September, 1960. The pH of the solution throughout was 8·9 to 9·0, and liquor flow through the decarbonator was 1,000 gal/h. The results are for hydrogen sulphide removed by the first tower. In every example, the sulphide content of the gas leaving the second tower was less than 10 gr/H_2S/100 ft³, and leaving the last tower was clean according to the Gas Referees' Standard Test.

TABLE 4.—*Percentage Removal of Hydrogen Sulphide by the Stretford Process at the Linacre Plant of the North Western Gas Board.*

pH	Partial Pressure Hydrogen Sulphide at.		Gas Rate (Mill. ft³/d)	Mass Transfer Coeff. (lb moles/ft³h/at.)
	In	Out		
1	2	3	4	5
8·8	0·0035	0·0010	4·8	1·18
	0·0035	0·0010	4·7	1·15
	0·0040	0·00117	4·9	1·15
	0·0045	0·00117	4·9	1·29
	0·0042	0·0010	3·3	0·94
8·9	0·0050	0·0005	2·5	1·16
	0·0032	0·00067	4·8	1·51
	0·0040	0·00083	4·8	1·53
	0·0037	0·00083	5·5	1·56
	0·0040	0·00067	4·3	1·55
	0·0042	0·00067	5·0	1·82
	0·0043	0·00067	4·5	1·65
	0·0042	0·00083	4·4	1·42
	0·0040	0·00083	4·6	1·45
	0·0037	0·00067	4·8	1·62
	0·0038	0·00083	5·2	1·59
	0·0038	0·0010	5·3	1·41
	0·0037	0·00083	4·8	1·42
	0·0035	0·00050	4·4	1·69
	0·0035	0·00083	5·2	1·45
	0·0040	0·00083	4·7	1·47
	0·0040	0·0010	5·2	1·40
	0·0042	0·00083	4·4	1·44
	0·0037	0·00067	4·5	1·48
	0·0042	0·00133	6·5	1·45
	0·0043	0·00067	4·1	1·54
	0·0047	0·00067	4·3	1·65
9·0	0·0040	0·00083	6·8	2·14
	0·0040	0·00067	5·8	2·03
	0·0038	0·00067	5·5	1·97

V DISCUSSION

Compared with oxide boxes, a liquid purification system occupies less ground space, has a lower capital cost, has a small and steady demand upon labour, and with this reagent produces a sulphur that can be converted to a saleable product. Compared with other liquid purification reagents, anthraquinone disulphonic acids have the advantage of being stable, non-corrosive, non-poisonous and water-soluble. Alkaline solutions of this reagent can reduce the hydrogen sulphide content of a gas stream to well below the required standard. Most of the visitors to the laboratories and plants during the past year have asked the following three questions:—

(1) Does this process give complete removal of hydrogen sulphide?

(2) How much does it cost to operate?

(3) What side reactions are involved?

In all the systems, whether in the laboratory or on a larger scale, the aim has been to operate with the gas fed to the last washing bay containing less than the Gas Referees' limit of hydrogen sulphide. Thus, on a plant with six washing bays, the gas leaving bay 5 should contain less than 1 p.p.m. of hydrogen sulphide. Sometimes, the plants have been overloaded to find out what they are capable of handling and which section of the whole plant first shows the effects of overloading, but most of the time the plants have had two bays rather than one fed with "clean" gas. There is no doubt that the reagent, under the recommended conditions of operation, is capable of removing hydrogen sulphide continuously to well below the Gas Referees' Standard.

The results obtained from Rochdale Road for hydrogen sulphide removal are low and variable because of uneven distribution of liquor from the two drilled pipes across a bay of oblong cross-section. At Linacre, the old distributors were replaced with a new trough system and the results are comparable with results from Whitchurch, taking into account that the Whitchurch packing had double the surface of the Linacre packing.

The economics of this process cannot be calculated accurately until a plant is designed and built to operate with this reagent; however, an estimate may be made, using the results obtained. From Table 3, an empty tower gas velocity of 1·1 ft/s will give a first-tower removal of at least 80 per cent of the hydrogen sulphide at pH 8·9 or 9·0, and the following towers will each remove between 80 and 90 per cent of their inlet loading. The gas velocity is lower than desired, but the overall process is limited by other factors. This gas velocity is equivalent to a throughput of 2·5 mill. ft³/d. of gas, or 4·1 mill. therms/a.

OPERATING COSTS:—

	£/annum.
Liquor circulation (24A at 400V)	360
Air Compression (30A at 400V)	450
Soda Ash added (20 tons at £15/ton)	300
Rotary Vacuum Filter (power cost)	25
Decarbonation (steam cost)	200
Labour for operation and maintenance at £25/week	1,300
	2,635

Initial cost of materials, with replacement period of 24 months.

	£
Anthraquinone disulphonic acid (2,500 lb @ 6*s.*/lb)	750
Soda Ash (8 tons @ £15/ton)	120
	870

Operating cost is thus £3,070, which is 0·18*d.*/therm.

By far the greatest part of this cost is for labour and power, and if for any reason it were decided to replace the solution after 12 months' operation instead of 24 months the cost of operation would be £3,800, which is 0·22*d.*/therm.

The only reason for replacing the liquor in the plant would be due to an accumulation of dissolved salts formed in side reactions. At Whitchurch, which is the only new plant operated under the Authors' control, the dissolved solids have risen by 4 per cent in 18 months' operation, which is equivalent to between 2 and 2½ per cent of the sulphur processed being converted to soluble salts. Tests in the laboratory have shown that satisfactory operation can be continued with large quantities of dissolved salts in the washing medium. One laboratory-scale apparatus has been operated after the solution was artificially loaded up to 20 per cent by weight of sodium thiosulphate. When the dissolved solids in the washing liquor increase, the difference in solubility between the two isomers of anthraquinone disulphonic acid becomes apparent. The 2:6 isomer is far less soluble than 2:7, and the 2:6 is quickly thrown out of solution by thiosulphate as shown in Figure 8. However, for the purpose of oxidation-reduction reactions with hydrosulphide ions, the 2:7 isomer is equally as effective as the 2:6, so the use initially of a 1 per cent solution of A.D.A. ensures that there is 0·5 per cent of the 2:7 isomer in solution in the presence of thiosulphate contents up to 60 per cent concentration.

At both Rochdale Road and Linacre, the sulphide loading of the liquor has been greater than at Whitchurch, and variable plant-operating conditions have led to rapid increases in thiosulphate content over short periods of time. In both plants, the thiosulphate content has reached 7 per cent of the circulating liquor after seven months of operation. Thiosulphate is formed most readily when air is blown through solutions containing free hydrosulphide ions. However, if the hydrosulphide has attached itself to the anthraquinone disulphonic acid as shown on the right hand side of equation 2, which means that time has been allowed for this equilibrium to be established, then the thiosulphate formation is much less than found when hydrosulphide solutions are blown with air. The higher the pH of the solution and the higher the temperature, then the greater is the formation of thiosulphate.

For several weeks at Linacre the hot liquor from the decarbonator, rich in carbonate and of high pH, was fed into the reaction tank where free hydrosulphide was present (the water gas at Linacre did not contain appreciable amounts of cyanide) and the temperature of the circulating liquor reached 40°C. During this period, the thiosulphate content of the liquor increased rapidly. No system of operation has been found, using A.D.A. in alkaline solution, that does not produce some thiosulphate; however, providing the liquor leaving the reaction tank is sulphide-free and the circulating liquor not allowed to increase in temperature, the conversion of sulphide to thiosulphate is small as shown by operation at Whitchurch.

Should the gas stream contain hydrogen cyanide, the alkaline washing medium will absorb hydrogen cyanide; however, the dissociation constant of 1×10^{-9} allows the dissociation of only half the hydrogen cyanide absorbed at pH9. Hence, some of this cyanide will be removed from the solution by the air blown through the oxidizer, and the lower the pH of the washing medium the more will be lost in this manner. Here again the formation of some thiocyanate when washing gas streams containing hydrogen sulphide and hydrogen cyanide cannot be avoided, and the sodium carbonate converted to sulphate, thiosulphate and thiocyanate must be replaced, thereby increasing the total dissolved solids and causing the precipitation of some of the 2:6 isomer of the anthraquinone disulphonic acids. As with thiosulphate, the rate of formation of thiocyanate increases with pH and liquor temperature.

Routine tests have shown that there is a variation in the reaction rates of commercially produced anthraquinone 2:6, 2:7 disulphonic acid, which cannot readily be explained. It has been found that a small quantity of iron, complexed with a sequestering agent to prevent the precipitation of iron sulphide in the gas-washing stage, will ensure a reagent of uniform activity. Results are given in Figure 9 for the addition of 50 p.p.m. of iron in order to show the effect of such additions to the reaction curve. The change in reaction rates due to the addition of iron is much greater than can be accounted for by the use of sequestered iron at the working pH level. Curve 1, Figure 9, shows how much sulphide is equivalent to the iron introduced.

In the calculation of operating costs, no credit has been claimed for the sulphur produced, which, for the example given of operation at Rochdale Road, would amount to more than 300 tons in a 12-month period. The washed sulphur cake, after drying, has a purity in the range 97 to 98 per cent, and after treatment in an autoclave, may be obtained as a molten product of 99 per cent purity. Should further purification be required, it may be carried out by activated-clay treatment of the molten product from the autoclave, by acid treatment of a solution of sulphur, or by distillation.

Sulphur sold at a profit of £1/ton will represent a reduction in cost of purification of 0·015*d.*/therm. By subtracting the equivalent of £2/ton of sulphur as a profit from the operating costs, calculated at 0·18 to 0·22*d.*/therm, and by adding capital charges on a new plant for liquid purification in the range 0·08 to 0·10*d.*/therm, there is an overall purification cost of the order of 0·25*d.*/therm.

VI IMPROVEMENTS: VANADATES

(A) Introduction

The Stretford Process is limited in its economic operation by the sulphide loading in the liquor; about 40 p.p.m. in solution may be converted to sulphur in the reaction tank, and the loading may be increased to 150 p.p.m. if the corresponding thiosulphate formation is accepted. The slow reaction to form sulphur necessitates long delay times, large volumes of liquor and large tanks, hence, much of the work has been directed to finding a means of increasing the reaction rates. The most successful of the many additives tried has been sodium vanadate, and initially the aim was to increase the speed of reaction between hydrosulphide and anthraquinone disulphonic acid to produce sulphur. However, it was found that the reaction rate depended upon the vanadate concentration, and during the oxidation of hydrosulphide to sulphur there was a transfer

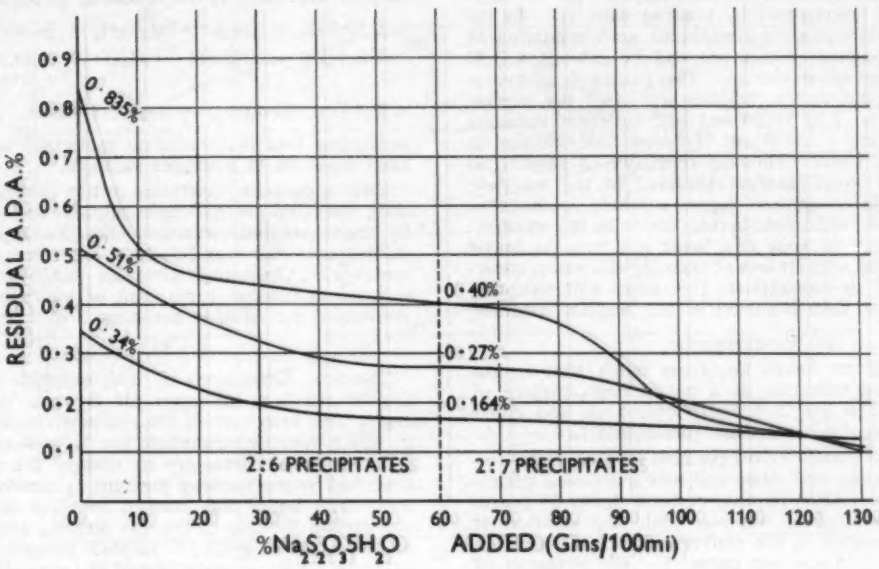

FIGURE 8.—*The Effect of Sodium Thiosulphate on A.D.A. Solutions.*

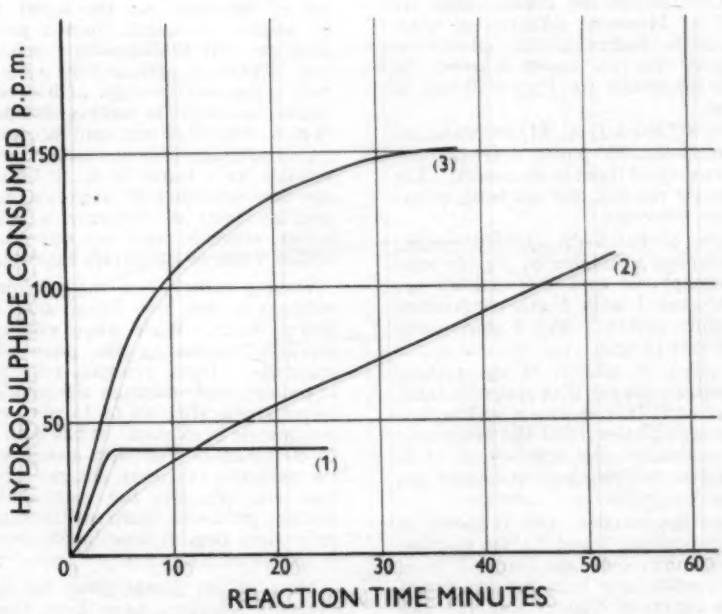

FIGURE 9.—*Effect of Chelated Iron upon A.D.A. Solutions.*

of $V^5 \rightarrow V^4$. A solution of sodium vanadate alone will react with hydrosulphide to produce sulphur, but the solution cannot be regenerated by blowing with air. In the presence of anthraquinone disulphonic acid, oxidation of the reduced vanadate is completed, and the reduced A.D.A. is regenerated by air oxidation. The oxidation of hydrosulphide to sulphur by the vanadate was rapid, the sulphur being visible after 1 to 3 min and with sufficient vanadate present converting a 250 p.p.m. hydrosulphide solution to sulphide-free in 5 min. Thus the formation of sulphur no longer depends upon oxygen dissolved in the solution, so it is possible to convert bigger sulphide loadings to sulphur and still feed sulphide-free liquor to the oxidizer. Also, the system will work at a lower pH than the initial Stretford Process, without loss of washing efficiency, ensuring a reduction in thiosulphate formation and obviating any necessity for decarbonation of the washing medium.

(B) Experimental

The results given below are from batch tests in the laboratory, using solutions of a commercial mixture of anthraquinone 2:6 and 2:7 disulphonic acids and either sodium orthovanadate or sodium metavanadate.

Figure 10 gives curves for 0·5 per cent solution of anthraquinone disulphonic acid alone and with increasing quantities of vanadate. After 15 min, curve 1 shows 65 p.p.m. of sulphide converted to sulphur, while the addition of vanadate has resulted in the conversion of 120 p.p.m. on curve 3 and 325 p.p.m. on curve 4. The presence of vanadate for curve 4 has increased the conversion of hydrosulphide to sulphur by a factor of 5, and the solution is almost "sulphide-free" in this 15-min period.

On repeating the experiments, using vanadate solutions without any anthraquinone disulphonic acid as shown in Figure 11, it is possible to convert 325 p.p.m. hydrosulphide to sulphur in 15 min, but the concentration of vanadate required is M/50, double the concentration for the results from Figure 1. However, solutions of vanadate after reduction with hydrosulphide, cannot be regenerated by blowing air into the liquid, whereas the solutions used to obtain the results for Figure 10 can be reoxidized by air blowing.

The solution containing M/100 A.D.A., M/300 Vanadate (Figure 12) has been loaded with 200 p.p.m. hydrosulphide and regenerated by air blowing 10 times in succession. The reaction rates determined for the first and the tenth reduction showed no significant difference.

The effects of variation of the hydrosulphide loading upon the percentage conversion to sulphur by a given solution of anthraquinone disulphonic acid and vanadate are shown in Figure 13. Curves 1 and 2 are overloading the washing medium, while curves 3 and 4 show complete conversion to sulphur in 15 min.

Figure 14 shows the effect of dilution of the washing medium when reacting with equimolar hydrosulphide loadings. The concentrations of A.D.A.-vanadate and hydrosulphide have been successively halved and the percentage conversion plotted against time to give curves 1 to 5. It is clear that the more dilute the solution the longer the time required to reach the "sulphide-free" condition.

The effects of pH upon the reaction rates is shown in Figure 15. At pH values between 9 and 10, the reaction rate is considerably lower than over the range 8 to 9. The use to which these results have been put for design purposes is shown in the curves of Figures 16*a*, 16*b* and 16*c*. For a given hydrosulphide loading in the liquor, it is possible to predict the percentage converted to sulphur in a given time. A similar series of curves at a lower pH value are shown in Figures 17*a*, 17*b* and 17*c*.

The vanadate is responsible for the reaction producing sulphur according to the following mechanism:—

$$4\ NaVO_3 + 2H_2S \rightarrow Na_2V_4O_9 + 2S + 2NaOH + H_2O$$

$$Na_2V_4O_9 + 2NaOH + H_2O + 2\text{A.D.A.} \rightarrow 4NaVO_3 + 2\text{ A.D.A. (reduced)}$$

$$2\text{ A.D.A. (reduced)} + O_2 \rightarrow 2\text{ A.D.A.} + 2H_2O$$

indicating that two vanadate molecules are required for each molecule of hydrogen sulphide.

Over a period of operation of two months in the laboratory, with coal gas/hydrogen sulphide and carbon dioxide/hydrogen sulphide mixtures, the conversion of HS^- to thiosulphate has been less than 1 per cent of the sulphide removed. Operating with an air/hydrogen sulphide mixture containing 1 per cent of hydrogen sulphide, the conversion has been in the range 2 to 3 per cent.

(C) Discussion

The low conversions of hydrosulphide to thiosulphate are due partly to the lower pH at which the washing processes have been carried out and partly to the reduced time in which free hydrosulphide ion is present in the liquor. It is no longer necessary to remove the carbon dioxide absorbed by the washing medium by means of decarbonators. The liquor was allowed to reach equilibrium with the carbon dioxide in the gas stream, and the reduction in percentage of hydrogen sulphide ionized in solution was balanced by the increased speed of conversion of hydrosulphide to sulphur. In the laboratory, no accumulation of water in the plant was noticed, since the weight of sulphur produced was small, but it will be necessary, on large-scale operation, to evaporate the water produced by the reactions to form sulphur and used to wash the sulphur removed at the filter.

However, the major improvements associated with the use of vanadate are the speed of reaction and weight of sulphur produced from a given volume of washing medium. At Whitchurch, a solution containing 0·5 per cent A.D.A. at pH9 and 40 p.p.m. sulphide has operated with a thiosulphate yield of between 1 and 2 per cent. A similar thiosulphate yield is obtained using 0·5 per cent of A.D.A. with 0·12 per cent of sodium vanadate and 320 p.p.m. sulphide, thus increasing the capacity of the washing solution by a factor of 8. It is not necessary to employ low concentrations of vanadate, for with the appropriate concentrations of vanadate a solution containing 1,000 p.p.m. sulphide may be converted to "sulphide-free" within 5 min in laboratory experiments.

Having achieved a rapid removal of sulphide from solution, it has been found that oxidation becomes the slowest stage. When using vanadates, a number of side reactions appear to take place which produce coloured materials. These products take from 20 to 60 min to re-oxidize, and, although the solution may be suitable for recirculation after 10 to 15 min, these coloured products accumulate in solution. It has been found that the addition of 50 p.p.m. or iron with a sequestering agent accelerates the oxidation reactions, ensures rapid and complete oxidation and prevents the accumulation of coloured side reaction products. Such oxidation promotors are necessary only when large hydrosulphide loadings are involved, *i.e.*, in excess of 200 p.p.m.

Most of the results given for operation with A.D.A.-vanadate solutions have been from laboratory tests in batch and dynamic systems. The Whitchurch plant was converted to operation with an A.D.A.-vanadate solution in November, 1960, but at the time of writing, detailed results are not available. The pH of the washing medium

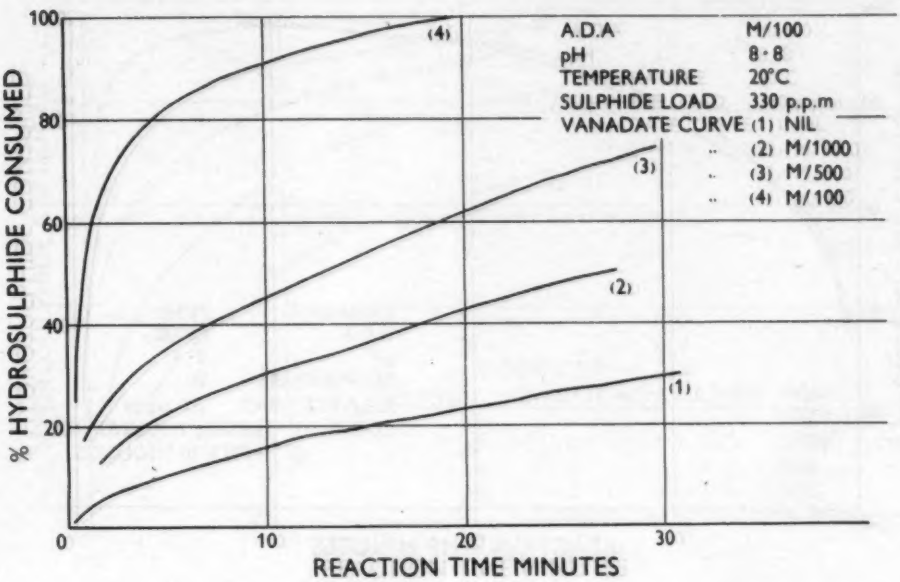

FIGURE 10.—*Effect of Addition of Vanadate to A.D.A. Solutions*

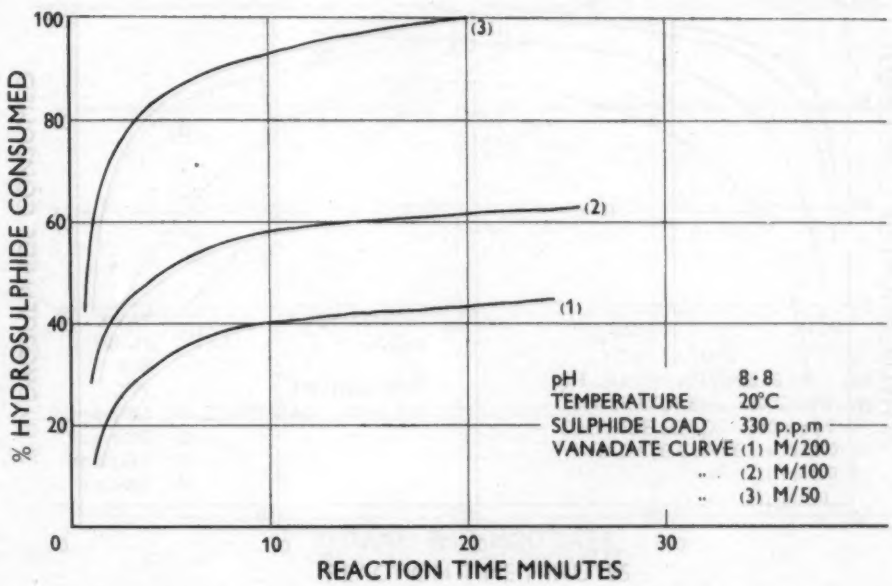

FIGURE 11.—*Reaction Rates of Vanadate and Hydrosulphide.*

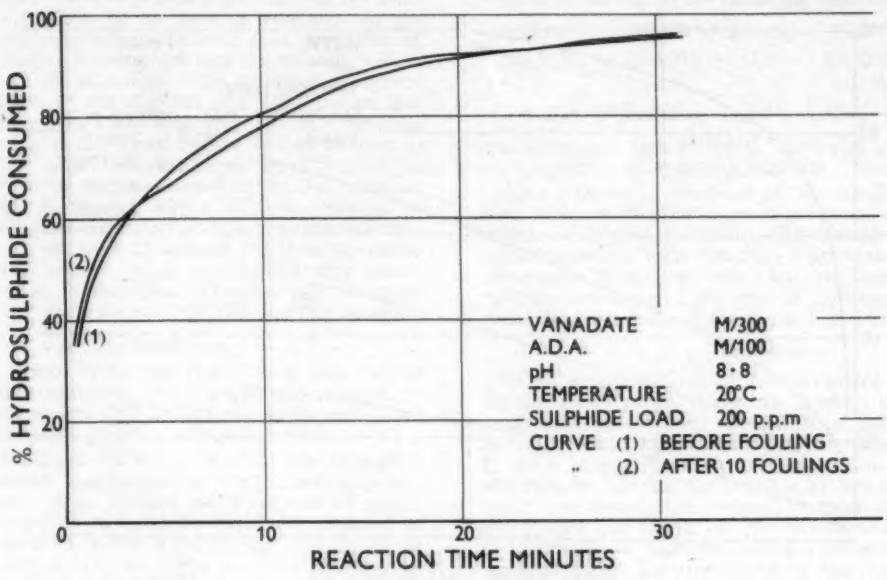

FIGURE 12.—*Successive Fouling of A.D.A.—Vanadate Solutions.*

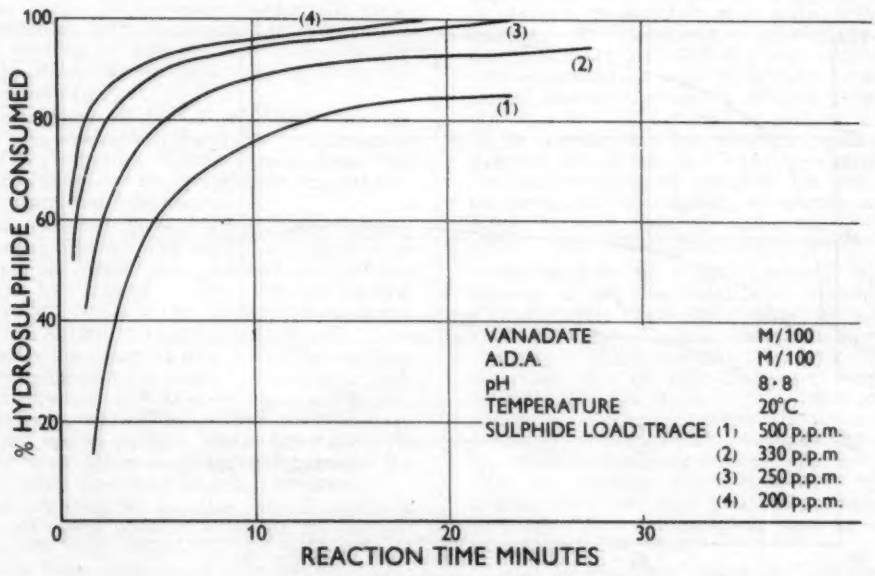

FIGURE 13.—*Effect of Sulphide Overload on A.D.A.—Vanadate Solutions.*

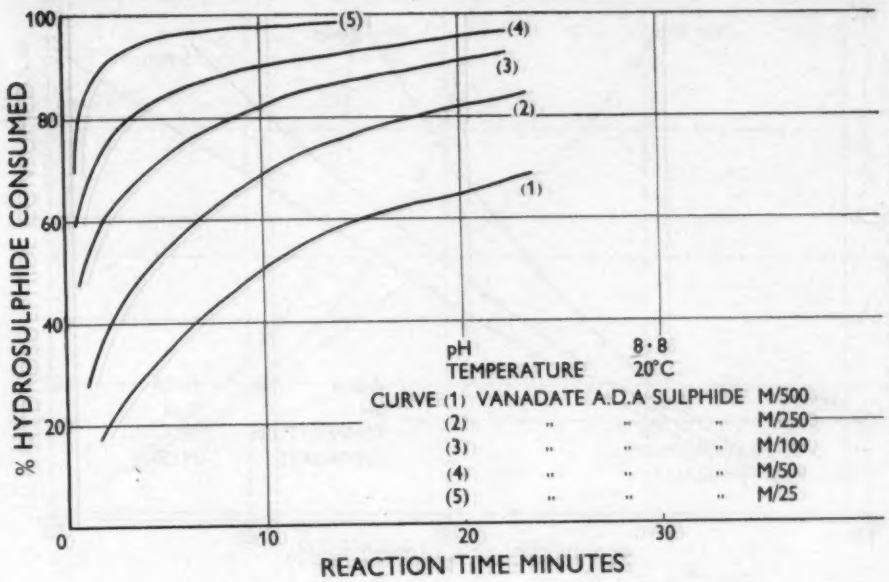

FIGURE 14.—*Effect of Dilution upon Reaction Curves.*

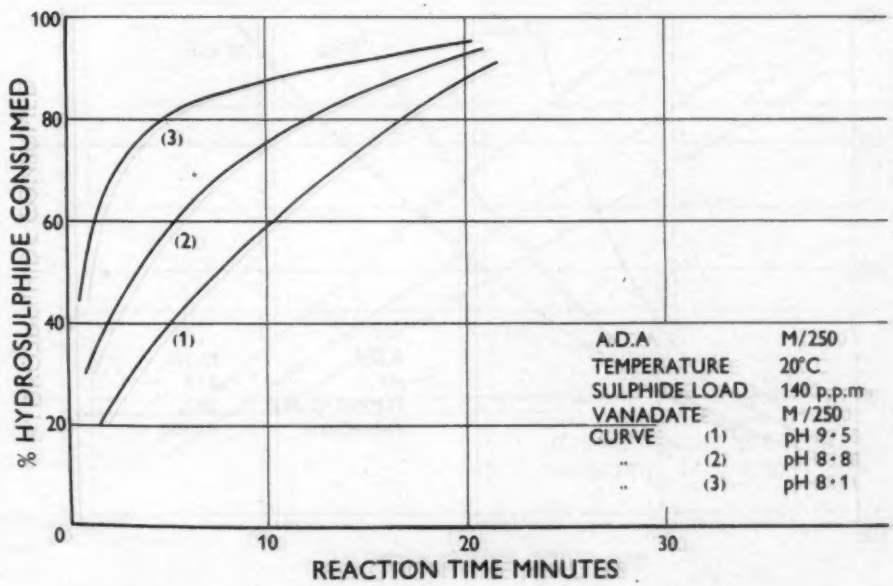

FIGURE 15.—*Effect of* pH *upon Reaction Rates.*

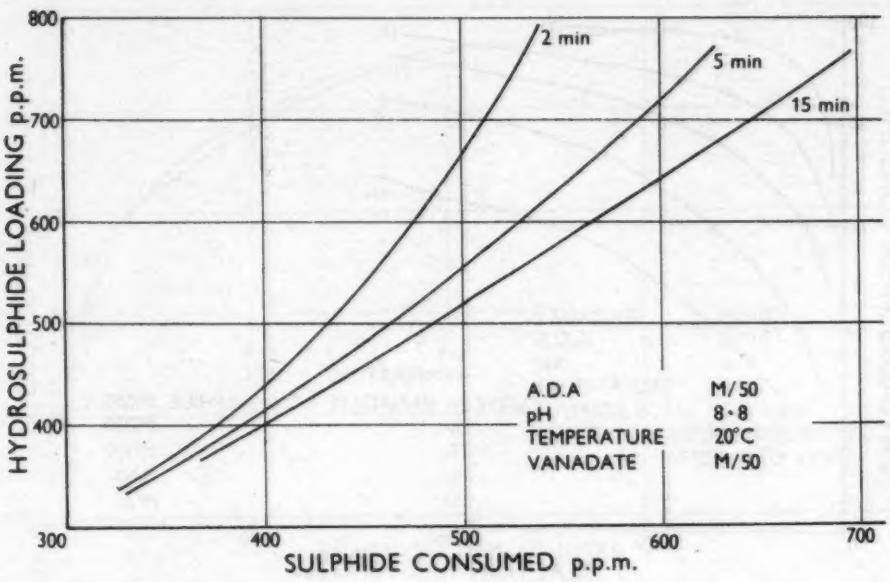

FIGURE 16*a*.—*Design Curves.*

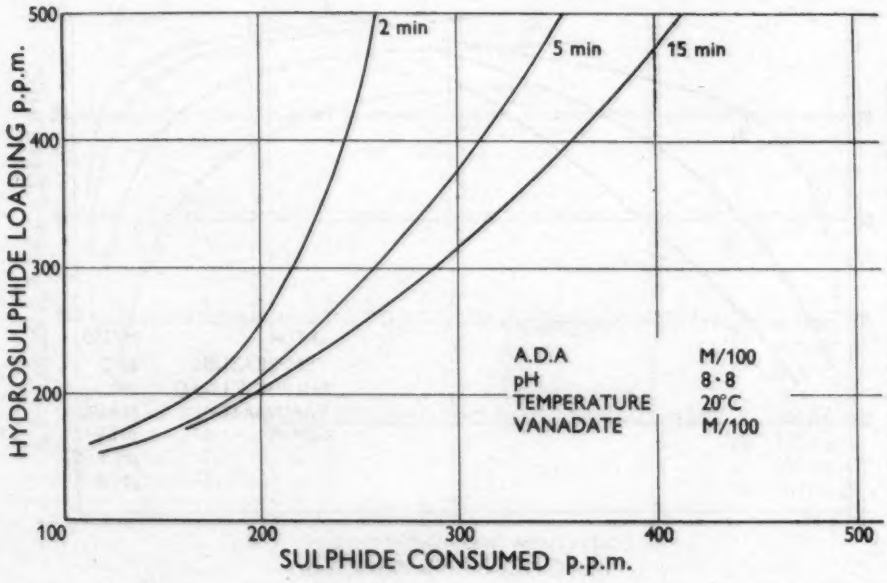

FIGURE 16*b*.—*Design Curves.*

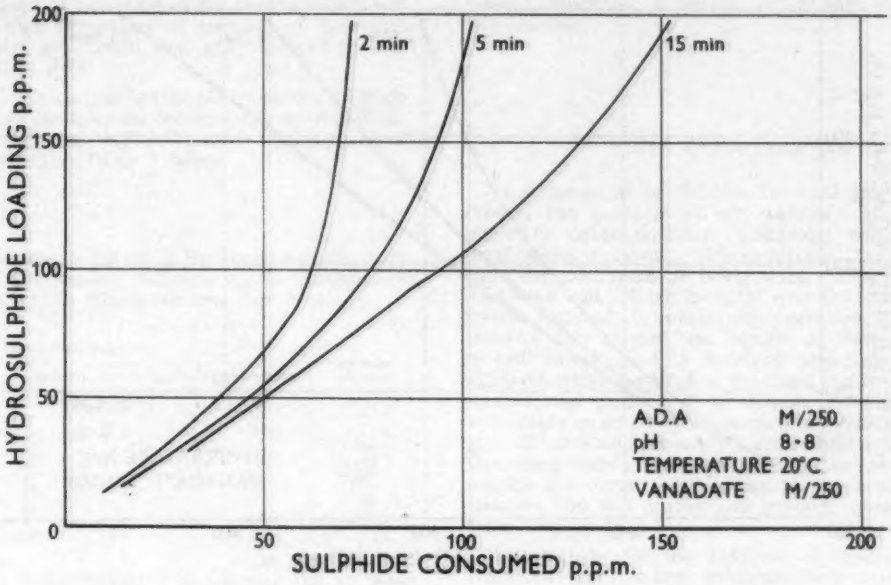

FIGURE 16*c*.—*Design Curves.*

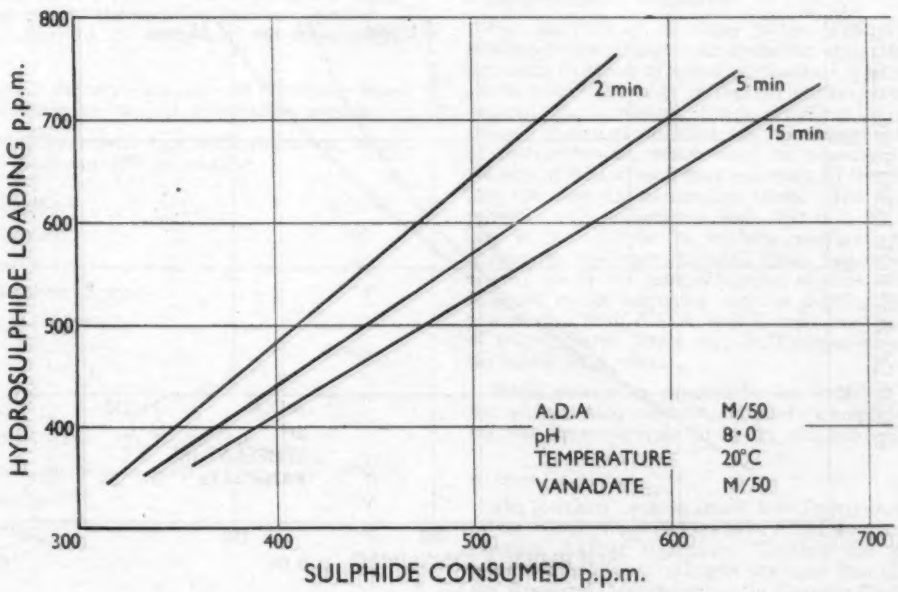

FIGURE 17*a*.—*Design Curves.*

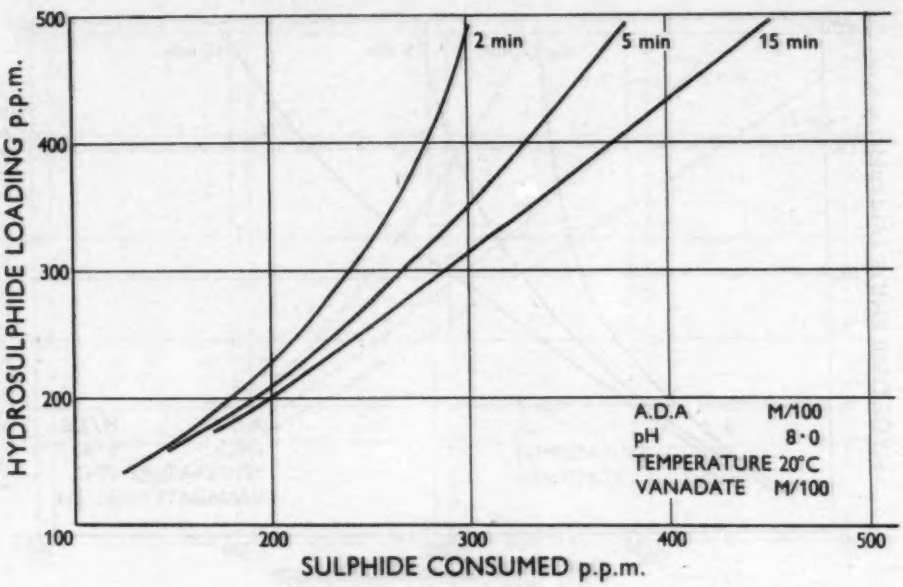

FIGURE 17*b*.—*Design Curves.*

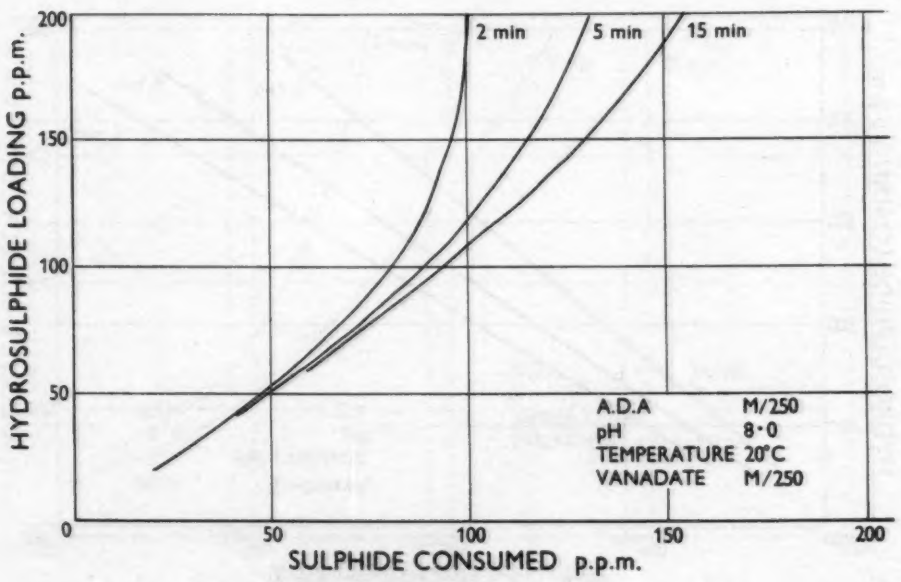

FIGURE 17*c*.—*Design Curves.*

in the absence of decarbonation has been reduced to 8·5 to 8·6, but the speed of oxidation of the hydrosulphide has maintained the high percentage of removal of hydrogen sulphide from the gas stream that was achieved by the Stretford Process at pH9.

A 10-day trial was carried out to determine the sulphide loading that could be removed continuously by the Whitchurch plant, using an A.D.A.-vanadate solution, and results are presented in Table 5 below:—

TABLE 5.—*Percentage Removal of Hydrogen Sulphide with A.D.A.-Vanadate Solution at the Whitchurch Plant of the North Western Gas Board.*

Hydrogen Sulphide				Gas flow (ft³ h)
Inlet (gr)	Bay 1 Outlet (gr)	Bay 2 Outlet (p.p.m.)	Bay 3 Outlet (p.p.m.)	
1	2	3	4	5
280	20	5·4	1·2	9,000
200	20	7·2	0·6	9,000
230	20	9·2	0·6	9,000
250	30	12·5	0·4	9,000
210	30	3·0	0·7	9,500
210	20	2·4	0·6	8,500

It was found to be necessary to increase the air flow to the oxidizer in order to achieve complete oxidation of the circulating liquor, and a small rotary vacuum filter was brought in, for the duration of this trial, to provide continuous sulphur removal.

Although the cost of reagents per unit volume of solution is more than the cost in the original Stretford Process, the hydrosulphide loading in the A.D.A.-vanadate liquor would be increased, and the solution can be expected to operate longer, due to a reduction of thiosulphate formation.

Thus, to compare the previous costs at Rochdale Road with a possible costing for an A.D.A.-vanadate process:—

Throughput may be raised to 6 mill. therms/a, which is equivalent to 320 p.p.m. HS^- in solution.

OPERATION COSTS:—	£/year
Liquor Circulation	360
Air Compression	450
Soda Ash Addition (5 tons)	75
Rotary Vacuum Filter	25
Labour	1,300
	2,210
INITIAL REAGENT COSTS FOR 30,000 GAL:—	
Anthraquinone disulphonic acids	900
Sodium Vanadate	500
Sodium Carbonate	200
Soluble Iron	50
	1,650

Over a period of two years, operating costs are 0·12*d.*/therm, while over four years the cost is 0·10*d.*/therm. Including capital charges and allowing no profit for the sulphur produced, it should be possible to operate at 0·2*d.*/therm.

VII CONCLUSIONS

As a means of purification for coal gas, the Stretford Process can compete on an economic basis with other liquid or oxide purifiers. Compared with other liquid purification reagents, anthraquinone disulphonic acids have the advantage of being stable, non-corrosive, non-poisonous and soluble in water over the range of concentration required for satisfactory operation. Alkaline solutions of this reagent are capable of washing fuel gases to well below the Gas Referees' Standard for hydrogen sulphide, while the sulphur produced can be filtered easily, washed and purified to a saleable product. Compared with oxide boxes, a liquid purification system occupies less ground space and demands lower capital and labour costs. Operating costs consist mainly of power to circulate and oxidize the liquor, and labour for operation and maintenance, and this process can produce sulphur as distinct from foul oxide.

This process for the removal of hydrogen sulphide from coal gas has been examined very thoroughly in the laboratory, and much information has been obtained on the behaviour of the materials involved. There is little doubt that it can be operated successfully on a large scale for gas works purification at high and low pressures, and every indication that there are many other useful applications, such as the removal of hydrogen sulphide from hydrogen/sulphide air mixtures in the viscose spinning and transparent-paper industries.

The addition of vanadate to the original solutions of anthraquinone disulphonic acids has improved their performance in terms of speed of production of sulphur from the hydrogen sulphide in the gas stream and has thereby reduced the incidence of side reactions to yield thiosulphate. Vanadate addition has also increased the loading of hydrosulphide, which may be converted by a given volume of liquor, and thus has reduced the liquor circulation rate and size of reaction tanks. The reactions in the presence of vanadate are such that it is no longer necessary to decarbonate the washing medium when employed to remove hydrogen sulphide from fuel gases containing from 1 to 10 per cent of carbon dioxide, all of which is reflected in the estimated costs of purification using these processes. With A.D.A. alone, costs may be of the order of 0·25*d.*/therm, while with A.D.A.-vanadate they should be below 0·2*d.*/therm.

World patents are pending for the Stretford Process using the sodium salts of anthraquinone disulphonic acids and for the improvements involving the use of vanadates.

Acknowledgments

The Authors wish to thank the Chairman and Members of the North Western Gas Board and the Directors of The Clayton Aniline Company, Limited, for permission to present this paper. Thanks are also due to members of the Research Department at the Clayton Company and the Scientific Department of the Gas Board for co-operation in the preparation of the material for this publication, and to the staff of the Manchester, Mid-Cheshire and Mersey Groups of the Gas Board associated with the large-scale operation of the process.

LITERATURE REFERENCES

[1]Bottoms, R. R. U.S. Patent 1,783,901 (1930).

[2]Sperr, F. W. Jr. *Proc Amer. Gas Assoc.*, 1921, **3**, 282 to 364.

[3]Sperr, F. W. Jr., and Hall, R.E. U.S. Patent 1,533,773 (1925).

[4]Townsend, L. G. *Inst. Gas Eng. Comm.* 429. *Trans. Inst. Gas Eng.*, 1952-53, **102**, 874.

[5]Powdrill, J. *Inst. Gas Eng. Comm.* 551. (1959).

[6]Sperr, F. W. *Gas Age-Record*, 1926, **58**, 73.

[7]Gluud, W., and Schoenfelder, R. *Chem and Met. Eng.*, 1927, **34**, 742.

[8]Giammarco, G. Italian Patent 537564 (1955), 560161 (1956), 565320 (1957).

[9]Gollmar, H. A. U.S. Patent 1,719,177 (1929), 1,719,762 (1929).

[10]Jacobson, D. L. U.S. Patent 1,719,180 (1929).

[11]Evans, E. V., and Stanier, H. British Patent 168504 (1921).

[12]Davis, J. E., Mills, J. E., and Ryder, C. *Gas Council Res. Comm. G.C.45.*

[13]Eymann, C. *Gas-u-Wasserfach*, 1948, **89**, 10.

[14]Bähr, J. *Brennstoff-Chem.*, 1955, **36**, 129.

[15]Bayerlein, K. *Gas, Wasser, Wärme*, 1954, **8**, 25.

[16]Mai, K. L., and Babb, A. L. *Indus. Eng. Chem.*, 1955, **47**, 1749.

[17]Dryden, I. G. G. *J. Soc. Chem. Ind.*, London, 1947, **66**, 59.

[18]Garner, F. H., Long, R., and Pennell, A. *J. Appl. Chem.*, 1958, **6**, 325.

PRESENTATION, DISCUSSION AND REPLY

Presentation

Dr. E. Brunner presented this paper and summarized its contents.

Discussion

Mr. G. U. Hopton (Director, London Research Station, The Gas Council) :—I have great pleasure in opening the discussion. I think it was 21 years ago that I first met Dr. Nicklin on a benzole plant. We had a happy collaboration there in developing the vacuum process for benzole recovery.

This paper is the result of collaboration between the development section of an Area Gas Board and the research section of a dyestuffs and chemicals company. Although one is not given the details of how this collaboration started, one can imagine that Dr. Nicklin, from his experience in purification, knew what sort of compound he was looking for and discussed the possibilities with Dr. Brunner, who knew what sort of compound was available.

The Stretford Process uses a remarkable compound : stable, non-toxic, non-corrosive, water-soluble 2 : 6 and 2 : 7 isomers of sodium anthraquinone disulphonate. These are equally active, but the 2 : 6 isomer is far less soluble, and in future it may be practicable to work with the 2 : 7 isomer only, which, I believe, is now available commercially. However, we have just heard from Dr. Brunner that the relative costs may favour the mixed isomer. The Stretford Process is, I suggest, a considerable improvement over the Manchester Process, because it employs a fully dissolved reagent and, therefore, yields a better quality sulphur.

The London Research Station includes as part of its research programme for The Gas Council a study of liquid reagents for the removal of hydrogen sulphide. We have worked with plain quinone and with iron-ethylene-diamine-tetra-acetic acid. We were not the first to work with the latter compound. We have found that the latter is particularly promising, subject, of course, to its being stable on prolonged use, which has yet to be decided.

Unfortunately, we did not learn of the work by the North Western Gas Board on anthraquinone disulphonate until we received notification of the patent application. I say " unfortunately " because we should gladly have given any help we could in carrying out tests. From our own point of view, frankly, we might not have pursued some of our own lines quite so far. As soon as we did hear, however, we got in touch with Dr. Nicklin, and, since we carried out some laboratory tests at atmospheric pressure on the Stretford reagent, members might like to hear briefly about them.

We have found that, for these mixed anthraquinone disulphonates, the overall mass transfer coefficient for absorption of hydrogen sulphide in the washer is lower than that for quinone or for iron-ethylene-diamine-tetra-acetic acid except at a high pH. Indeed, the Stretford Process as first developed included decarbonation of part of the liquor stream in order to keep up the pH and, consequently, the absorption rate. Another advantage of quinone and iron-ethylene-diamine-tetra-acetic acid over plain anthraquinone disulphonate is that the first two react very rapidly in the washer and do not need a delay tank for the formation of sulphur from hydrogen sulphide.

The Stretford Process, like all purification systems that depend on regeneration of the liquor with air, is bound to give some absorption of hydrogen cyanide going to thiocyanate. Indeed, it is most suitable for gases free from hydrogen cyanide. It has considerable possibilities in the purification of air in viscose works, the purification of refinery gases and the recovery of sulphur from hydrogen sulphide gases, which would otherwise be treated in a Claus kiln. With fuel gases containing hydrogen cyanide there is, however, some formation of thiocyanate, and this, together with thiosulphate, which is also formed, constitutes an effluent problem. This involves not only the disposal of the effluent, but some loss of reagent ; this is a fact that must be faced. After all, are we not all familiar with the problems of effluent disposal from all sorts of plant?

The conditions for minimizing thiocyanate and thiosulphate formation are to avoid high temperature or high pH in the liquor even locally, and to aerate the liquor before bringing it into contact with the gas.

I have already mentioned the large delay tank needed with sodium anthraquinone disulphonate for the sulphur formation to occur from the absorbed hydrogen sulphide. This is followed by a slow oxidation stage in the aeration vessel. So far, these comments—I am sure the Authors will appreciate that this is the sort of comment they want—have pointed out some disadvantages. The advantages, of course, are obvious to us all. The next move made by the Authors was the addition of vanadate. This appears to have been a very shrewd move indeed.

We have found in our tests in the laboratory that this improves the absorption so that the mass transfer coefficient at pH 8·1 is as good as that without vanadate at pH 8·8. Thus, the absorption rate now approaches that of quinone or iron-ethylene-diamine-tetra-acetic acid. The addition of vanadate improves also the oxidation of hydrogen sulphide to sulphur, so that the reaction time is reduced to about one-third of that without vanadate.

Thus, the delay becomes much less and also, as a consequence, thiosulphate formation is not as high as without vanadate. Moreover, there is a double advantage because being able to work at a lower pH has the effect also of reducing thiosulphate formation. Indeed, the Authors tell us that the overall rate of thiosulphate formation may be only 0·1 of that without vanadate. Another advantage, as Dr. Brunner has already pointed out, is that, because a lower pH can be tolerated, there is no need for decarbonation of part of the liquor stream, and this is a valuable economy.

Even more recently, the Authors have tried the addition of a small quantity of iron complexed with a sequestering agent, and I hope we shall hear more details about this in the future. What, for example, would this reagent do by itself?

It is probably wise of the Authors, in calculating operating costs, to give no credit for the sulphur produced, because the market is so poor that many would hesitate to accept a balance sheet containing any return for the sulphur. Nevertheless, the figures quoted by the Authors for the difference that would be made if a profit were allowed on sulphur are very interesting. Without such credit, a

total cost of just under 0·3*d.*/therm is given for the original Stretford Process, and 0·2*d*/therm with the addition of vanadate.

We all know that these estimates compare very favourably with oxide purification. It is, perhaps, worth pointing out that the advantage of lower first cost is much more certain than that of lower operating costs until more experience has been gained. The process is very promising, but much is still going on and we look to the future for experience in the operation of it.

Mr. J. E. Davis, O.B.E. (Croydon ; Chief Technical Officer, South-Eastern Gas Board) :—In addition to my thanks for this paper, I am grateful to Dr. Nicklin and Dr. Brunner for two other matters. The first is the opportunity to make a confession, and the second, the opportunity for collaboration.

At the 24th Autumn Research Meeting in 1958, it was my privilege, with two colleagues, to present a paper discussing the removal of hydrogen sulphide from gas. We were then working with methylene blue as the dyestuff, and aniline as the solvent. That paper contains the statement :—

> " In the three years of operating experience with this process no other complicating side reactions have been observed, nor has there been any reason to suspect that such reactions may take place ".

After 40 years of experimenting with wet purification processes, I should not have made such a statement. Within three weeks, serious complicating side reactions began to show themselves. Finally, we had to recognize that methylene blue, under conditions of plant operation, did not display the chemical stability which it had appeared to show during a series of laboratory experiments, each lasting for over 100 h. The dyestuff underwent successive stages of de-methylation, producing sticky, resinous substances to which various names were given. There was deep disappointment amongst those who had worked so hard and who had seemed within reach of a notable success.

Then came the news from the North Western Gas Board of the employment of a dyestuff of undoubtedly greater stability than that which we had used. We had constructed for The Gas Council, at the Board's Sydenham works, a high-pressure pilot plant for operation with the methylene blue solution, and it seemed reasonable to make this plant available for tests with the anthraquinone derivative which was being used by the North Western Gas Board. Dr. Nicklin's ready response to this suggestion was not only a matter of great encouragement to our staff who had suffered the serious reverse, but will, I hope, though I am certainly not again going to prophesy, lead to a valuable and much needed development.

Reference has already been made to the particularly significant improvement which has taken place since the first publication of news about the Stretford Process. All wet purification processes using an aqueous solution for hydrogen sulphide removal and oxidation absorb this impurity initially as hydrosulphide. Those who have worked on this, know that the hydrosulphide must be destroyed as quickly as possible. If this does not occur, there is risk of the formation of polysulphide and oxidation to one or more of the series of sulphur-oxyacids. Initially, oxidation of hydrosulphide in the Stretford Process was too slow and the inevitable consequences of slow oxidation showed themselves. The addition of vanadate as an accelerator is, I believe, a major and, probably, critical advance.

Mr. R. J. S. Thompson (Head of Chemical Engineering Division, W. C. Holmes and Company, Limited) :—It gives me particular pleasure to have this opportunity of contributing to the discussion on this very important paper by Dr. Nicklin and Dr. Brunner on hydrogen sulphide removal by the Stretford liquid-purification process. In one way and another, I have been associated with Dr. Nicklin for nearly 30 years in connexion with the treatment and purification of town gas, and it is no surprise to me that he has succeeded in producing, in collaboration with his various colleagues, this very important liquid purification process.

I have had the good fortune to be able to follow the development of the process almost from its inception, and it was clear from the beginning that Dr. Nicklin had discovered something of great promise. It is a credit to Dr. Nicklin, Dr. Brunner and their colleagues that they have developed it to its present stage of efficiency, overcoming one problem after another in a masterly fashion.

In addition to the full-scale plants at Whitchurch, Rochdale Road and Linacre Gas Works, which are described by Dr. Nicklin and Dr. Brunner in their paper, the firm with which I am associated received an order from the South Western Gas Board to convert one line of its Stapleton Road liquid purification plant (Manchester Process) to the Stretford Process. The converted plant went into operation on 5th November, 1960, and represents the first commercial plant, other than those owned by the North Western Gas Board, to go into operation. This plant treats 6 mill. ft³ of coal gas daily containing 600 to 700 gr of hydrogen sulphide/100 ft³, the process being the original Stretford Process without the addition of either vanadate or iron. The sulphide concentration in the circulating liquid is of the order of 100 to 120 p.p.m.

The results of six months' operation show that the gas can be purified well below the Gas Referees' Standard by the original Stretford Process. They have also shown quite clearly the disadvantages of the original Stretford Process, namely, formation of thiosulphate and thiocyanate. In consequence, the concentration of dissolved salts has now become quite considerable. Sequestrated iron has now been added to the solution, but the results of this are not yet available.

At the present moment, another plant supplied by W. C. Holmes and Company is actually being commissioned. This was the first commercial order received for a Stretford Process plant by any licensee. It is most interesting in that the gas mixture to be dealt with comprises 60 per cent of hydrogen sulphide and 40 per cent of carbon dioxide. A point of interest about high concentrations of hydrogen sulphide is that the circulating solution will automatically rise to a high temperature, which in this particular case will be between 50° and 60°C.

Another interesting point about such highly concentrated gases is that the volume of washing solution can be greater than the volume of gas to be washed.

The greatest improvement in the Stretford Process relates, of course, to the addition of vanadate compounds to the washing solution. I have studied the curves of Figures 10 to 17*c* in very great detail. A point of considerable interest and very great importance about them is that, to a large extent, they can be reduced to mathematical terms.

In this connexion, Figure 14 is specially interesting and shows five different curves for five different concentrations of vanadate/ADA/sulphide, all three materials being present in the same molecular concentration. Every one of these curves follows with amazing accuracy the mathematical formula for a second-order chemical reaction, whose formula is

$$t_{0\cdot5} = \frac{1}{100\,M}$$

where $t_{0\cdot5}$ is the half-life in minutes and M is the molecular concentration.

The full formula for use when the reactants are present in different concentrations is :

$$t = \frac{2\cdot303}{100\,(a-b)} \quad \log\frac{b}{a} + \log\frac{a-x}{b-x}$$

where t = time in minutes,
a = initial concentration of hydrogen sulphide,
b = initial concentration of vanadate, and
x = fraction converted.

Not all the curves presented in the paper follow these formulae exactly, but they are all of the same form. Time prevents my discussing them in further detail, but a study of these curves and others that I have had the opportunity of examining leads to certain conclusions.

As the concentration of reactants in solution increases, the half-life and the total reaction time decrease in proportion. It should, therefore, be possible to improve the performance of the plant and reduce its cost by increasing the concentration of the reactants to the maximum possible. In particular, the vanadate concentration should be greater than that of the hydrogen sulphide, so that there is a substantial quantity of unreacted vanadate left when the hydrogen sulphide has completely disappeared.

The greater the concentration of reactants, the greater will be the cost of the solution, but this will be largely offset by the reduced

quantity required. It should also be noted that the value of the solution made up from $\frac{M}{100}$ ADA and $\frac{M}{100}$ vanadate is approximately 8*d.*/gal. By comparison, the value of ethanolamine solutions used for a similar purpose in the refinery and natural gas industry is from 4*s.* 6*d.* to 6*s.*/gal. If this is acceptable in the petroleum and natural gas industry, a similar price should be acceptable for the Stretford solution. The advantage of using strong solutions is particularly noticeable when high-pressure gases are to be treated.

One of the great advantages of the Stretford Process is its simplicity. The instrumentation required on this plant is very small indeed, and to my mind this is a very important matter. There is very little to go wrong and the plant can be run by semi-skilled operators. Technical supervision amounts to no more than occasional checks on the composition of the washing solution, and the usual testing of the outlet gas.

It seems to me that the Stretford Process has an exceedingly wide range of applications far outside the gas industry. So far as the gas industry is concerned, it can be applied to all gases met with and is especially applicable to the low-sulphur-concentration gases now being produced in increasing quantities.

Dr. C. T. Cowan (The Fullers Earth Union, Limited, Redhill, Surrey) :—I was very interested to hear Mr. Hopton's comments on the by-product sulphur produced by the Stretford Process, and it is this that I should like to discuss. It is all-important that the by-product sulphur produced in the United Kingdom should be of the highest possible purity. In this way, by-product sulphur from the Stretford Process can command at least the same basic price as can Claus sulphur, now made in the United Kingdom refineries, and Lacq sulphur, which is being imported in ever-increasing quantities from France.

From all these sources, the sulphur is as good as 99·7 per cent purity, which is not reached in Frasch sulphur, which at one time dictated quality levels. Furthermore, Claus sulphur commands the interest of those needing sulphur for specialized uses, e.g., production of carbon disulphide.

The wet sulphur obtained from the Stretford Process is rather badly contaminated with such things as water and inorganic and organic impurities since it is produced as a filter cake straight from the unit. Straightforward drying of this sulphur yields material of unattractive colour containing up to 5 per cent of impurities. Not only is this sulphur unsuitable for direct use in acid manufacture, but there is a loss of anthraquinone disulphonic acid solution from the system, the weight of which is at least equal to the weight of sulphur obtained.

However, the Fullers Earth Union, Limited, has developed a three-stage process (involving an activated-earth treatment) on the basis of laboratory experiments, that reduces carbonaceous impurities in such sulphur to less than 0·05 per cent, and inorganic impurities to zero, and allows for the recirculation of ADA solution. Tentative estimates on the processing costs indicate that this high-purity sulphur could be produced competitively with existing supplies of high-purity sulphur.

In answer to Mr. Hopton, may I suggest that the possibility of partly offsetting the cost of operating the Stretford Process by the value of the by-product sulphur should, therefore, not be too lightly dismissed.

Mr. L. G. Townsend (Chief Chemist, Mersey Group, North Western Gas Board) :—In spite of the manifest advantages of liquid purification for the removal of hydrogen sulphide from fuel gases, such processes have had a chequered history in this country, and it is of some interest here to ask why this should be so. The Ferrox Process and the later-developed Manchester Process previously described in papers to this Institution have not as yet received general acceptance, largely due to the fact that the full advantages of the process were not achieved except in special circumstances that were not generally available. With the Manchester Process, for example, the most favourable results were achieved when the gas being washed contained significant amounts of cyanide, and it was only then that the process became really competitive with oxide boxes. The mass transfer coefficients were increased by at least 50 per cent when cyanide was present, so that, although continuous washing down to gas examiners' limits was possible with water gas containing no cyanide, the power consumption was relatively high and the costs correspondingly increased. Even so, there were circumstances when such additional costs could be justified. Cyanide, when present, was being continually lost in side reactions, and, therefore, the addition of cyanide from an external source was not possible, on account of the high cost of suitable reagents.

The Authors of this paper have mentioned some of the questions that have been asked by visitors to the plant ; having been intimately concerned with the plant at Linacre, in this connexion I should add two further questions to those cited by the Authors : (i) What has the new process got that the Manchester Process has not? (ii) What happens to the sulphur removed from the rotary filter? It is largely with these questions that my contribution is concerned.

The Stretford Process possesses a considerable advantage in the first place because in the simple application it uses a very stable reagent, which from plant experience appears to be almost indestructible. The stability of these anthraquinone derivatives is quite extraordinary, and this is indeed fortunate, since they are relatively expensive. It is for this reason that very careful watch on mechanical losses of reagent must be kept. This is not, however, a preoccupation in plant operation. The second advantage arises because, unlike the reagent in the simple Manchester Process, operating without cyanide, the reagent in this case is water-soluble and not in suspension. The third advantage lies in the ease of oxidation of the reduced compound, which causes a considerable reduction in the power consumption, which formed such a large proportion of the costs in the original Manchester Process.

As explained in the paper, a limitation to plant throughput is set by the amount of free hydrosulphide in solution, and when the theoretical loading of the plant liquor is exceeded soda ash consumption increases. At Linacre, for example, in the circumstances outlined in Table 4 the sulphide loading is appreciably above 40 p.p.m., and soda ash to the extent of 80 lb/mill. ft^3 of gas treated had to be added to maintain the pH at the required level. It would seem that, without using additives, the limit to plant performance is set by the residence time in the reaction tanks. Higher throughput when the oxidizers are operated co-currently are achieved at the expense of increased soda ash consumption, and at Linacre the stage was eventually reached when the performance of the oxidizers set the limit to the throughput. This was the state of affairs with the Manchester Process as normally operated. It is also evident that, when the sulphide content of the gas is low, the plant throughput is then governed by the washing capacity of the towers, which is well in excess of 6 mill. ft^3/d. The fact that the performance of the oxidizers limited the plant throughput was due in part to the poor condition of the oxidizer spinners, some of which were not in operation. There would seem to be a case for a combination of co-current and counter-current operation of the oxidizers and it would be of great interest to know what the efficiency of air usage might be in the most favourable circumstances. It is of interest to record that at no time was there evidence of hydrogen sulphide in the oxidizer air vent even on heavy loads.

Coming to the question of sulphur recovery, it should be realized that the sulphur cake removed from the vacuum filter, when treating cold or warm sulphur sludge from the plant, contains a high proportion of water—in the region of 50 per cent. Filtration of boiled preheated sludge reduces this figure considerably to about 30 per cent and this was the method employed in the Manchester Process at Linacre. There are no particular difficulties in drying this material, but so far the complete recovery of sulphur has not been followed up at Linacre. There is undoubtedly a good case for the use of autoclaves in the Stretford Process, since they were only discarded in the original Manchester Process because of the complications due to iron in suspension. Wet sulphur sludge can be responsible for a considerable loss of anthraquinone reagent, and water washing of the cake in a rotary filter is not very successful. Calculation will show that the loss of reagent in this way does not significantly affect the costs of the process for gases containing a low burden of hydrogen sulphide, but for gases containing 1 per cent and over the cost of reagent lost in this way may be appreciable. It might be argued, however, that the annual charge of reagent suggested by the Authors might then be dispensed with.

Up to the present time, we have had no experience with the use of vanadates at Linacre, but experiments at Whitchurch have shown their value not only in increasing plant capacity, but also in reducing the need for decarbonation. This latter complicates

the plant layout and also increases operating costs, since the steam demand may be considerable. It is of the greatest interest to know whether there is any loss of vanadate in side reactions, particularly when there are departures from the concentrations of 0·05 per cent anthraquinone sulphonic acid. It is evident that the two compounds are mutually essential. It is also of interest to determine the effect of vanadate on the cyanide that is frequently present in fuel gases. One would expect increased thiocyanate formation, which could be advantageous in that the discharge of free hydrogen cyanide is as undesirable as that of hydrogen sulphide. A further point concerning the use of vanadate is whether the reduced pH might not introduce corrosion difficulties. No obvious corrosion has ever occurred at Linacre, and this has been attributed in the main to the high pH prevailing.

Once again, the quotation of costs in *d.*/therm seems illogical and the cost/lb of sulphur removed might be more acceptable. There is one further point of some interest in that accumulation of solids on the board filling of the towers, which can be a very considerable disadvantage of the process, has not so far occurred at Linacre and it would be of interest to know the Authors' experience on other plants.

This paper represents a major step forward in the field of liquid purification, and the costs quoted are competitive with other methods and are an improvement on results put forward for the Manchester Process. The final method of sulphur recovery could reduce these still further.

Mr. G. S. Cribb (Chemical Engineer, London Research Station, The Gas Council) :—I should like to confine my remarks to the short section of the paper dealing with the simultaneous absorption of carbon dioxide and hydrogen sulphide, although, if decarbonation can be avoided, this consideration may now be irrelevant. In their Introduction to the paper, the Authors state that the pH is maintained by using a sodium carbonate/bicarbonate mixture, but that ammonium or other alkaline salts may be used. This is, of course, true, but would not the use of ammonia have two severe disadvantages, namely, loss of selectivity and the exclusion of air as a means of decarbonation?

The absorption of carbon dioxide is, as is stated, controlled by slow chemical reaction, the mechanism being given as the hydration of the carbon dioxide molecule. There is also the reaction with hydroxyl ion, which, at the pH quoted, is 3·5 times faster. If ammonia is present, on the other hand, absorption proceeds *via* a third mechanism, namely, the formation of carbamic acid, and, for a 0·5N solution at a pH of 9·0, the free ammonia concentration is such that this latter reaction will be about 1,000 times faster than the hydroxylation reaction. As a consequence, ammonia solutions absorb carbon dioxide more readily than do soda or potash solutions and are thus less selective. The work by Eymann, Bahr and Bayerlein on selective washing, referred to by the Authors, was with ammonia solutions.

It is stated, in Section III of the paper, that the absorption of hydrogen sulphide is controlled mostly by the gas-film resistance. This suggests that the gas velocity should be increased at least to the point where the resistances are equal. I presume that this is what the Authors have in mind when they say, in Section V, that the gas velocity of 1·1 ft/s is lower than desired. Would they elaborate, however, on the qualifying statement that " . . . the overall process is limited by other factors "? I can appreciate that, when converting an existing " Manchester " installation to the Stretford Process, gas is not an independent variable, but do the Authors imply that they would not increase the velocity in a new installation specifically designed for their process?

Mr. R. Pollard (London ; Technical and Sales Manager, R. and J. Dempster, Limited) :—As a representative of one of the licensees, I consider it a little audacious to pretend to make critical comment on the Stretford Process at this early stage in its history, especially since most of our knowledge comes directly from our good friends in the North Western Gas Board. However, as one of the licensees, we are pleasantly surprised at the wide interest in the process. This is particularly noticeable on the Continent, where this country has so often been the buyer rather than the vendor.

We have obtained orders for a plant in Antwerp, for refinery gas, and another in England, to be commissioned in October and November, 1961, respectively. The plant for Belgium is of a capacity of about 11 mill. ft³/d and a pressure of 8 atmospheres and a hydrogen sulphide burden of 300 gr/100 ft³. The second plant will work on gas from a reforming plant at a rate of 7 mill. ft³/d, but the sulphur is lower at 5 gr/100 ft³.

I venture to suggest that the Authors' paper has been produced, perhaps, a little early in the development of the plant. It is only in the later pages that one gets a hint that the plant could be an attractive proposition. Since we have heard Dr. Brunner, we now know that they are talking about a different order of hydrogen sulphide burden in the liquor circulated.

I should refer particularly to the end of the second paragraph of Section VI(c), which, I think, is the only reference to a hydrogen sulphide concentration in the liquor of the magnitude that we must have. Again, the opening words of Section VI are, surely, an unlucky choice. Are we, by reading on, to assume that another name is given to the process when vanadate and iron are incorporated?

I fail to understand the reason for including costs at the end of Section VI(c), particularly as they represent a prediction and since, more importantly, they are based on a hydrogen sulphide concentration of only 320 p.p.m. I must, therefore, ask Dr. Nicklin whether he considers the value of 320 p.p.m. to be economic and real.

I have no hesitation in saying that the paper gives an excellent and truthful—almost too truthful—account of the skilled and worthy development work that the Authors and their colleagues have applied for two or three years, but I am a little afraid that the reader without other knowledge might be left with a feeling that the process is not as worthy of consideration as it really is.

The application of the process to gases under pressure is not dealt with, and it would be unfair to suggest that this aspect and many others known to the inventors should have appeared in the paper today. It is, nevertheless, a very real problem in those industries where the process has excited most interest. The absorption of gases into the liquid under pressure in the absorbers could lead to explosive mixtures in the air leaving the oxidizers, and such a plant requires thoughtful design to avoid this contingency without wasteful loss of energy.

Side reactions and the rate of production of the resultant compounds are, of course, of prime importance, and it is known that work will have to be undertaken to ascertain the controllable limits.

The design of the oxidizer and the air distribution system is still a very open question, and power costs and efficiency are closely related : for example, if high power costs are incurred through intimately and efficiently mixing air and liquid and/or endeavouring to produce the smallest possible bubble, it may well prove better to increase the capacity of a cheap vessel and/or the quality of air to save on the overall power costs.

There is little doubt that the capital cost of plants operating on the Stretford Process is moderate compared with many alternative systems, and running costs can be reduced by careful design and development to improve the carrying capacity of the liquor, the limitation of side reactions and attention to the mechanics of oxidation. Resolution of these aspects will undoubtedly place the process in an unassailable position.

The **President** : —It is of particular interest to know that your Company has secured a large export order for this process.

Mr. L. C. Bennett (Bristol ; Chief Chemist, Stapleton Road Works, South Western Gas Board) :—As a previous contributor has already stated, for the past six months the South Western Gas Board has been using the Stretford Process for the complete removal of hydrogen sulphide from gas produced in continuous vertical retorts, at Stapleton Road Works, Bristol.

It would, of course, be premature to express a firm opinion of this unique process after such a short period of operation, but it is thought that some comments on Dr. Nicklin's and Dr. Brunner's paper, based on experience at Bristol, may be useful.

There were at Bristol two plants, each of 6 mill ft³/d capacity, designed for and operated on the Manchester Process. Towards the end of 1960, one of these plants, suitably modified (mainly by the addition of an extra reaction tank, provision of a decarbonating plant and by the substitution of board filling for the splash-plate filling in the washers), was put to work using the basic Stretford Process. The usual problems associated with the introduction of a new process were encountered, notably in clearing the plant of the Manchester Process reagent together with the built-up deposits of six years' continuous operation.

A difficulty encountered early on was a large and entirely unexpected increase in back pressure across the washers, due to partial blockage of the board fillings by a deposit that proved to be mainly sulphur. This necessitated replacing the board filling with the formerly installed splash-plate filling to ensure satisfactory working during the winter peak-load period. The first washer (of five) has since been repacked with board filling using a modified trough system of liquor distribution, since when no blockage has occurred over a period of four months. The modified type of liquor distribution coupled with the introduction of spacers between the successive tiers of grids is thought to account for the non-recurrence of the blockage.

In view of this experience, it is now proposed to replace in all washers, as convenient, the splash-plate filling with board filling, on account of the greater washing efficiency of the latter.

The effect of temperature on the rate of reduction of the hydrosulphide by anthraquinone-disulphonic acid reagent as shown in Figure 2 of the paper is of particular interest. During a period of low gas throughput due to the increased back pressure caused by the partial blockage of the board filling, the temperature of the circulating plant liquor fell, partly due to the smaller amount of heat released by chemical reaction through the lower gas throughput and partly due to a lower atmospheric temperature. During this period, the hydrogen sulphide content of the outlet gas rose to well above Gas Referees' Standard. The restoration of normal gas throughput, together with a higher atmospheric temperature, enabled the circulating-liquor temperature to return to normal, and satisfactory purification was again obtained.

Once the initial teething troubles had been overcome and the decarbonating plant (which was completed some time after the changeover) was commissioned, the process proved to be satisfactory with regard to removal of hydrogen sulphide, and the converted plant is now purifying 6 mill. ft^3/d of continuous vertical retort gas to Gas Referees' Standard.

The sulphur produced by the Stretford Process at Bristol, after washing with hot water on the vacuum filters, contains up to 97 per cent sulphur on the dry basis. The potential loss of anthraquinone-di-sulphonic acid reagent in unwashed sulphur makes adequate water-washing of the sulphur necessary, the washings being returned to the plant circulating liquor. The addition of this water at Bristol has been found approximately to compensate for the loss of water that occurs during the decarbonation process. It is felt that, in order to produce a sulphur for which full value can be obtained, some form of autoclave treatment is desirable ; also, the complete recovery of the valuable anthraquinone-di-sulphonic acid reagent that such treatment will make possible will be equally important to the economics of the process.

It is stated, in Section V of the paper, that no system of operation has been found, using A.D.A. in alkaline solution, that does not produce some thiosulphate, *etc.*, and this has been the experience at Bristol, where the thiosulphate content of the plant liquor is rising at a rate rather greater than that quoted for Whitchurch. The use of vanadates to improve the reaction rate and thus reduce thiosulphate formation appears to be a most promising development but this has not yet been introduced at Bristol. This improvement may well be of great importance, as even a relatively slow rate of thiosulphate formation will ultimately mean not only the replacement of valuable reagent, but also the emergence of the problem of effluent disposal. Increasing interest in trade effluent on a nation-wide basis is indicative of the potential value of this process, providing that thiosulphate formation can be kept to a minimum.

It will be appreciated that the Bristol plant has been in action for a relatively short time using the basic Stretford Process only. During this period, the plant has demonstrated its ability to purify rated throughput to Gas Referees' Standard with complete reliability, the rate of thiosulphate formation being as previously indicated. It is felt, however, that, with the possibility of an accelerated rate of thiosulphate formation under summer conditions, appreciably more experience is necessary before any final conclusions can be drawn on the overall merits and economics of the process.

I should like to add my congratulations to Dr. Nicklin and Dr. Brunner on their conception of this elegant method of dealing with the difficult problem of complete removal of hydrogen sulphide, and on their presentation of this instructive and interesting paper.

I should also like to say on behalf of my colleagues at Bristol and myself how much we have enjoyed our close association with Dr. Nicklin and his staff on this Bristol project.

Written Contribution

Mr. J. K. Mottershead and **Mr. M. Landau** (Simon-Carves, Limited) jointly wrote :—The Authors are to be congratulated on a most interesting paper and on developing a most promising liquid-purification process.

Simon-Carves, Limited, apart from its interest in the standard gas works application, has been recently engaged in experimental work on the laboratory and pilot-plant scale on the Stretford reactions treating gas with high hydrogen sulphide concentrations. This work has confirmed our opinion that oxygen transfer, not hydrogen sulphide absorption, is the vital stage in the Stretford cycle at least as far as high hydrogen sulphide loadings of the solution are concerned. It has been found possible, by suitable choice of the reagent concentrations, to treat liquors containing as much as 1,500 p.p.m. of hydrogen sulphide. This would bring the size of plants handling highly concentrated hydrogen sulphide streams within reasonable proportions and make them an economic proposition. In connexion with this problem, we would ask the Authors whether they have considered means, alternative to tall aeration towers, of effecting oxygen transfer. In our experience in effluent treatment work, we have found that in biological systems, oxygen transfer can be achieved more economically in shallow stirred tanks than flooded aeration towers, and rates as high as 10 lb of oxygen/h.p./h are quite common.

In terms of our conditions on our Stretford pilot plant, this means we can achieve an oxygen transfer of 800 to 1,000 p.p.m./h without difficulty. As the Authors state, it is the oxidation reaction within the solution that becomes rate-determining, and any means of accelerating this has a great effect on the overall economics of the process.

In our experiments, we have found that the admixture of air to the gas to be purified, when permissible, has no detrimental effect and, in fact, is extremely helpful in the digestion of hydrogen sulphide and in reducing the load on the oxidizer. Thiosulphate formation is not increased under these conditions of working at ordinary temperatures, and is formed in the oxidizer only when an overspill of hydrosulphide ion from the delay tank takes place. Sulphur recovery under these conditions has been found extremely easy, since sulphur from these high-concentration gases appears to precipitate in granular form and virtually settles out of solution without additional need for concentration. This opens the way for the Stretford Process to treat gases containing up to 100 per cent of hydrogen sulphide and might even make it possible to use such plants as substitute for Claus kilns in the treatment of widely varying hydrogen sulphide effluent streams, particularly when the flow rate is variable. In the treatment of such effluent gas streams, with hydrogen sulphide concentration varying from zero to 100 per cent, this process would seem to offer great promise for the future.

Written Reply

The **Authors**, in reply, wrote :—In writing this paper, the Authors have tried to show how the Stretford Process has developed, but it is inevitable that, at the time of presentation and discussion more information will have become available. It is clear from the Authors' own work and the contribution of Simon-Carves, Limited, that the hydrosulphide loading in the liquor can be increased to 1,500 p.p.m., but such loadings can be achieved only from gases containing a high proportion of hydrogen sulphide. In practice, the plant design is no longer limited by the loading of hydrosulphide in solution, and should be based upon gas velocity and wetted surface of the packing, while the solution composition is selected to ensure the rapid conversion of the hydrosulphide obtained.

No details of pressure operation have been given in this paper, since no work has been carried out at Stretford on this application. As stated by Mr. Davis, the high-pressure pilot plant at Sydenham is being used for work with A.D.A. and A.D.A.-vanadate solutions, and it is hoped that information on pressure operation will form the subject of a future *Communication*.

Several speakers have referred to the formation of thiosulphate and thiocyanate. Thiocyanate formation, which is due basically to the absorption of hydrogen cyanide in the alkaline medium, is

considerably reduced by a lower pH value, but, below a pH value about 8·5, some of the absorbed hydrogen cyanide may be released with the effluent air from the oxidizers. This situation should be avoided, and the Authors would suggest that the hydrogen cyanide should be removed from the gas streams in which it occurs before the removal of hydrogen sulphide.

The Authors sympathize with Bristol on the formation of thiosulphate, which for some time has been greater than that experienced at Rochdale Road or Whitchurch indicated. Difficulties with reaction rates of the reagents were found, which were ironed out subsequently in the laboratory, but in the meantime a considerable amount of thiosulphate had been formed. The introduction of vanadate has reduced thiosulphate formation to such a degree that it is now less than 2 per cent, and probably nearer 1 per cent, of the sulphur admitted to the process.

Several speakers have pointed out that unless the sulphur cake is washed there will be a loss of solution from the process equal to the weight of sulphur produced, and to obtain a sulphur of high purity it is essential that the cake be washed before further processing. The purity of the washed cake will depend upon the gas from which it has been obtained, and, although the gas works purification train is highly efficient, there are traces of light tars, phenolic matter and gum-forming compounds, which are adsorbed by the sulphur and produce a dark sulphur on melting in an autoclave. Dr. Cowan might have enlarged somewhat on the process devised for purification, which involves the treatment of molten sulphur with an activated clay. This clay removes the tar and gummy compounds to yield a sulphur of 99·95 to 99·97 per cent purity at a cost well below its present market value. There are also certain applications in the veterinary and agricultural fields for the powdered sulphur obtainable by thorough washing of the cake to remove all inorganic material.

Oxidation is an essential part of the process and represents a cost of operation. Work is being carried out with injectors and the more efficient sintered metal and ceramic diffusers, particularly for oxidation of solutions working on high sulphide loadings. The tendency is to increase the depth of the oxidizer and hence the solubility of oxygen in the liquor, which, with the addition of 0·001 per cent of non-foaming surface active agents to reduce the bubble size, has given oxygen utilization efficiencies of the order of 25 per cent, which could rise to 40 or 50 per cent in some applications.

Most of the work carried out has been in solutions containing sodium carbonate and bicarbonate, but ammonia has been used with limited success. The Stretford Process plant was situated before the ammonia washer on the Rochdale Road works, and the ammonia in the coal gas was used to maintain the pH of the washing medium. However, difficulties arose in hot weather when the ammonia did not remain in solution ; the equilibrium pH fell to 8·3 and the solution was no longer able to purify the gas stream to the Gas Referees' Standard.

In a new installation that might be designed for the Stretford Process, the aim would be to increase the gas velocity from 1·1 ft/s, quoted in Section V, to about 3 or 4 ft/s to obtain more efficient absorption, the limiting factor now being entrainment of the washing liquor on the packing by the gas stream. The other factors at Rochdale Road included lack of reaction capacity, unsatisfactory form of oxidation and the high sulphide loading of the liquor if the gas washers were operated at more favourable gas velocities ; in fact, all the reasons for the transfer of operation from Rochdale Road to Linacre.

Finally, three questions from Mr. Townsend on operation with vanadate. The Authors have not found any loss of vanadate from solutions where the whole plant is operating. However, if the oxidizer is isolated and the liquor sulphided so that the concentration of sulphide exceeds that of vanadate, a black precipitate containing vanadium may be thrown out of the solution unless the vanadium is first complexed. The Authors have no experience at present of the operation of vanadate solutions with gases containing cyanides. So far as corrosion is concerned, the fall in pH from 9 to 8·5 is not likely to lead to any increase, and sodium metavanadate as used in this process is also used as a corrosion inhibitor in alkaline solutions.

THE IGNITION AND CONTROL OF TUNNEL BURNERS

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RESEARCH COMMUNICATION *GC*69

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I SUMMARY

A method of applying electrical ignition to tunnel burners supplied with a fully aerated mixture is presented. The method depends upon the fact that a flame initiated within a mixture nozzle or tube is swept forward by the flowing air/gas mixture. Design data for the application of this method of ignition to practical burners is included. Where there is danger of explosion, any system using main-flame ignition will require, for safety reasons, a controlled ignition time cycle and, of course, a flame detector. The development of a suitable commercial unit for use in a timed ignition cycle of 2 sec is described. In using a burner, it is usually necessary to vary its throughput, and several ways of doing this are considered, with particular emphasis on air blast tunnel burners. Complete burner control systems, both manual and automatic, are given that include various combinations of ignition with safety and throughput control.

II INTRODUCTION

The use of automatic control in industrial processes is becoming more widespread, and the Gas Industry must be ready with suitable equipment for these processes; in particular, it must have available automatic control systems for burners. The need for the automatic control of tunnel burners in industrial processes has been shown by the growing demands made upon the Instrumentation and Control Department of The Gas Council's Midlands Research Station, both by Area Gas Boards and by manufacturers of industrial appliances.

One of the basic requirements for automatic burner control is that the burner ignition should be automatic. More specifically, there is a demand for electrical ignition of tunnel burners, which arises for a variety of reasons. Some consumers value the convenience of " press button " ignition, and this facility should, therefore, be available, especially since it is offered by competitive fuels. Another

reason is where an installation is part of a large and complex process and its operation must be integrated into this. Sometimes, lack of accessibility to the burner necessitates remote ignition, and there are certain types of tunnel burner for which electrical ignition is the only possible automatic method. One of the main objects of the work reported in this Paper was to satisfy this demand for the electrical ignition of tunnel burners.

In some applications of tunnel burners, flame-protection equipment will obviously be required for safety reasons, and the provision of a general method of achieving this was another main object of the work.

When a tunnel burner is being used, it is, of course, necessary to control its throughput. The way this is achieved depends to some extent on the method by which the air/gas mixture fed to the burner is produced. For each method, there are a variety of control systems that can be used. It was, therefore, necessary to be selective in treating this part of the subject. Because of the wide application of air blast burners, most of the problems and enquiries received have concerned these, and, consequently, the throughput control systems discussed are mainly concerned with this type of burner. However, many of the methods given can be adapted to apply to burners supplied with air/gas mixtures produced in other ways. Many of these enquiries have been concerned with the control of special processes using air blast tunnel burners with large throughputs, often in the range 5,000 to 10,000 cu. ft/hr. Here a single burner can be employed, and it is, therefore, much easier to justify the cost of fitting automatic control and flame-failure equipment than is the case when a multiplicity of smaller burners are used.

Separate sections of the Paper deal with safety, throughput control and ignition. In practice, it is necessary to combine some or all of these in an integrated form, and various methods of achieving this have been worked out and tested under industrial conditions. Obviously, there is a very wide scope here, and only those systems that have been proved to be most suitable in general practice are included. There will always be the special requirement not catered for by normal methods, and it is only by following modern instrument and control trends that the Gas Industry can meet the competitive needs of industry.

III SAFETY

The safe operation of installations fired by tunnel burners will involve certain safeguards that in some cases will require the use of flame-protection equipment.

The industrial gas engineer has a wide choice of safety equipment at his disposal, and over the years several recommendations have been made by The Gas Council's Industrial Gas Development Committee, covering the use of this equipment on a variety of installations. It is not intended, in this section of the Paper, to deal with the many ancillary safety devices that may be required in any installation, since the I.G.D.C. Report No. 676/58 deals with this in some detail.

The difficulty of providing flame protection for tunnel burners is to find a suitable flame detector. The properties required are: a rapid speed of response, so that the principle of main-flame ignition (described in Section V of this Paper) can be applied to a fully automatic burner control system, and also the suitability for use in both high- and low-temperature applications. It is also desirable that the method adopted should be capable of integration with the burner and, hence, avoid difficulties associated with the correct location of individual components on site.

The purpose of this section is to describe a flame-detection system developed for tunnel burners and its incorporation in semi-automatic and fully automatic control units. In use, this equipment can safeguard against failure of the following:—

(*a*) Electricity supply.
(*b*) Gas supply.
(*c*) Air supply by the use of an air flow switch.
(*d*) Components prior to start-up.
(*e*) Process, through an interlock, e.g., high-temperature limit switch.
(*f*) Flame.

There is thus no need for separate air, gas or electricity failure-protection equipment, and this can provide good reason for fitting flame-failure units on furnaces although the cost may be prohibitive where many burners are used.

Most of the usual methods of flame detection are unsuitable because they have too slow a speed of response. One flame-detection method available that is suitable in this respect, relies on the property, which all flames have, of producing ionized particles; these can be detected by using a probe and circuit arrangements that respond to the conduction effect of the ions, or to the rectification effect, or to the conduction "flicker" effect due to ionic turbulence. The system using flame conduction is not as reliable as the other two since deposits of dust can cause flame simulation. All these ionization systems require a probe to be positioned in or near the flame, and this sometimes causes installation difficulties; in any case, a probe is not suitable for high-temperature applications.

Of the remaining commercially available flame detectors, only one type appeared suitable for application to tunnel burners. This detector operates on the infra-red radiation emitted from town gas flames and utilizes a type of cell developed for the detection of aircraft exhaust gases. This is the lead sulphide photo-resistive cell (Mullard type 61SV) sensitive to radiation of wavelengths of 1 to 3μ. Upon receipt of energy in this part of the spectrum, the resistance of the cell is reduced so that, if a constant current is passed through it, then the e.m.f. across the cell will vary according to the amount of energy incident upon it. Unfortunately, radiation of the same wavelength is emitted by hot refractory, and thus the resistance of the cell will be lowered by radiation from either flame or hot refractory. This difficulty had been overcome by the manufacturers of these units, by utilizing a property of all flames—that of radiation "flicker". The radiation intensity from a flame "flickers", whereas radiation from a hot refractory is steady, thus the potential across the cell will contain an a.c. component if a flame is being viewed, but will be purely d.c. if no flame is present and the cell is receiving steady radiation from a furnace wall. Due to the low signal level produced by this cell, an amplifier is used; this is designed to pass only the a.c. component produced when a flame is present, thus rejecting the effect of steady radiation. This amplified a.c. signal is then rectified to produce a d.c. potential that actuates a relay circuit. The relay has several electrical contacts attached to it, which are used to operate the various parts of the external circuit when a flame is detected.

In the initial experiments, air blast tunnel burners were used with the cell mounted upstream of the air nozzle and positioned so as to view the flame axially through the tunnel. This arrangement, shown in Figure 1, has the advantage

that the cell is now part of the burner, and the sometimes tedious job of sighting the cell during installation is avoided. It soon became evident, from these experiments, that the sensitivity of the commercial detection system described above was not sufficiently high to operate satisfactorily when used with some air blast tunnel burners. Upon investigation, it was found that the electronic unit had its a.c. amplifier designed to pass " flicker " frequencies of the order of 15 c/s and that above this frequency there was a rapid drop in amplification, it being some 40 times less at 50 c/s—an obvious advantage where " hum " pickup from a.c. mains might be troublesome. It then became apparent that there is a widely held belief that the flicker from all types of flame is a maximum at a frequency of about 15 c/s, and this is thought to stem from work on diffusion flames carried out some years ago. However, since there is no reported evidence to substantiate this with regard to tunnel burners, an investigation of flicker frequencies was felt to be necessary.

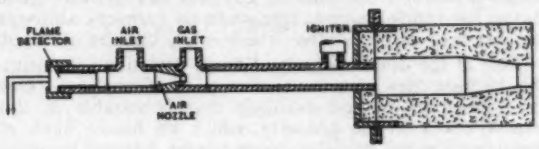


FIGURE 1.—*Air Blast Tunnel Burner Fitted with a Flame Detector.*

The apparatus used consisted of an infra-red cell (Mullard type 61 SV), together with a source of current as used in the commercial unit. The output was taken directly from the cell and, for convenience, fed into an endless-loop tape recorder. The loop was subsequently played back into a frequency analyser so that an analysis could be carried out without the inconvenience of having a burner running during this time. Recordings were taken of various sizes and types of tunnel burner at three levels of throughput, i.e., low, medium and high. The burners used were of the type designed by Francis.[1] The recordings were subsequently analysed, but the equipment did not allow analysis below about 25 c/s. It was found that every throughput from each burner produced a different frequency analysis, but there was a general pattern, a typical one being that shown in Figure 2.

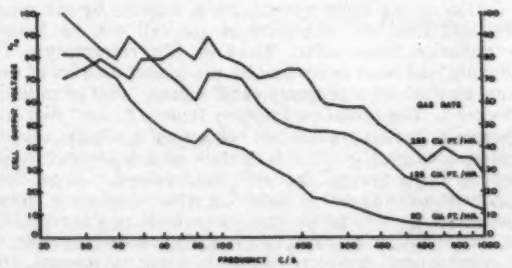


FIGURE 2.—*The Variation of Cell Output with Frequency for a 1 in. Type C Burner at Three Throughputs.*

From these results, it was decided to alter the frequency response of the amplifier to accept frequencies up to 70 to 90 c/s, with a cut at 100 c/s so that illumination from a.c. mains-operated lamps could be rejected. The necessary alterations were made to the electronic circuit and the unit was again tested and was found to work where it had failed to do so before. The manufacturers of the equipment have been very co-operative throughout this development period, and have made modifications to the electronic circuit so that a satisfactory flame detector is now commercially available.

It is, of course, necessary to include the flame detector in some sort of control unit that can be used to prevent the flow of gas if a flame is not established by the ignition process. The control units now commercially available have " safe start " protective circuits that prevent the flow of gas if there should be any fault causing flame simulation prior to ignition. They can also be used to safeguard against the failures listed in the introduction to this section. There are two general types of control unit available—semi-automatic and fully-automatic; both are capable of being operated by remote push-button.

(A) SEMI-AUTOMATIC CONTROL

The simplest unit incorporating a flame detector is a semi-automatic control unit; that is, one by which some functions are performed automatically, but there remains a considerable operator responsibility. This type of unit can be used to safeguard against failure of all the items listed at the beginning of this section. It is, therefore, useful where a burner has to be left unattended or where the addition of process interlockings may be required. However, its use is restricted to applications where a controlled ignition period is not necessary. For example, where local heating operations are performed in the open.

The choice of semi-automatic control for burners with main-flame ignition requires careful consideration since the ignition period is manually controlled. If an operator should depress the " start " button for an appreciable period of time, and if the ignition system should fail, an explosive mixture can be delivered into a confined space and an explosion could occur. It is important, therefore, to limit the application of this type of control to those cases where unburnt mixture is not a hazard. Operators should in any case be trained to press the start button for only a short period, and, if a flame is not established, to investigate the cause of the trouble.

(B) FULLY-AUTOMATIC CONTROL

For fully-automatic control a time-cycle controller takes all responsibility away from the operator, who has only to press a start button; in some cases, even this action may be replaced by a process switch. The ignition period is controlled to effect ignition within 2 sec. so that, if flame is not established within this period, the gas is turned off and an alarm is operated. The safety offered by this equipment is of a high order and a self-check is included during each start-up period so that, if an electronic fault should occur leading to flame simulation, the equipment will fail to safety and no gas will be passed.

(C) LIMITATIONS

The flame-detection system described above is satisfactory in the majority of cases, and is always safe. There are, however, two conditions that require special attention. In some circumstances it is possible for a stream of air passing over very hot refractory to cause modulation of the radiation from the refractory, and so simulate a flame. This does not result in a dangerous condition if a gas flow switch is incorporated in the system, and in any case it is difficult to think of a condition where re-ignition would not occur. The other application is where a very high refractory temperature is " seen " by the cell; this lowers the cell resistance so much that its sensitivity falls below that necessary for correct operation of the amplifier and flame relay. When this is encountered, the effect is that the flame is not detected and the unit will fail to safety. This may result in a " nuisance " shut-down. The remedy is

to provide a cooler background for the cell to "see", for instance, either by installing a pocket that will have a cooler end face in the refractory wall, or by resighting the cell so that the background is cooler.

(D) Additional Comment

A recent development in the flame-detection field is the Ultra Vision detector, which can sense the ultra-violet radiation emitted by all flames. It is claimed that the unit is not sensitive to emission from hot refractories; hence, it might well have a useful application in the high-temperature field where it is inconvenient to provide a cooler background for the infra-red type of cell.

The application of flame-failure equipment requires some justification where its cost is a considerable proportion of that of the whole installation and where, for safety reasons, it might not be considered essential. However, both the semi-automatic and fully automatic units have the facility of being operated from a remote push-button station, and it is a simple matter to incorporate process interlocks. For these reasons alone, their fitting might be considered worth while.

Some installations have many burners, and it is here that the cost of fitting flame-failure equipment might be considerable in relation to the total cost of the installation. For this reason, there is a need for a cheaper flame detector capable of being used in a multiple-burner control system. With this end in view, an investigation of other methods of flame detection is being carried out at the Midlands Research Station.

IV THROUGHPUT CONTROL

In using a tunnel burner, it is generally necessary to adjust the thermal output to meet the demand of the process to which it is applied. There is thus a need for the control of burner throughput, and since, in general, a process requires that a certain temperature be maintained, this means that the heat input to the appliance must change as the thermal load changes: for instance, the thermal input to a furnace will need to be much higher during the heating-up period than while it is being maintained at a particular temperature. It is, therefore, obvious that at least two rates of heat input to an appliance will be required, and it is often desirable that the control of these should be automatic. The type of control used will, to a certain extent, depend upon the method by which the fully aerated mixture supplied to the burner is produced.

METHODS OF PRODUCING AIR/GAS MIXTURES

Air/gas mixtures for tunnel burners can be produced by mixing machines, by the use of gas and air both supplied at pressure, by gas at pressure entraining air, or by air at pressure entraining gas (air blast).

(a) Mixing Machines

These are usually expensive, but are often used when the mixture is supplied to a large number of burners. In such a system, throughput control may be accomplished by turning burners up or down as required, since, in a good machine, the air: gas ratio of the mixture will not vary greatly with throughput.

(b) Pressure Gas with Pressure Air

This is often used for producing mixture at a fairly high pressure, since the actual mixing process involves very little pressure loss. Throughput may be controlled by means of coupled air and gas valves. The coupling can in many cases be achieved without undue difficulty. However, if accurate control of mixture ratio is required over a wide range of throughput, the design of the coupling becomes critical. Under these conditions, the design is specific to each installation.

(c) Pressure Gas

Injectors using pressure gas could be used in tunnel burners although they would not normally be employed, since, to obtain a reasonable mixture pressure, a very high gas pressure is required: for example, a gas pressure of about 2 lb/sq. in. is required to produce a mixture pressure of 1 in. w.g. However, the throughput of such a system can be varied quite simply by means of a valve controlling the gas flow to the injector.

(d) Air Blast

Compared with pressure gas, air blast is inexpensive, since reasonable mixture pressures can be obtained with moderate air pressures such as can be delivered by fans: for example, a mixture pressure of 1 in. w.g. can be achieved with an air pressure of about 3 in. w.g. Control of throughput is also relatively simple when a zero gas governor is used, since the throughput can be varied by means of a valve controlling the air flow.

METHODS OF CONTROLLING THROUGHPUT

From the above, it can be seen that, for systems using mixing machines or pressure air/pressure gas, there is an obvious way of controlling throughput in each case. However, there are several ways of controlling the throughput of air blast burners, and some of these are discussed below. The systems are presented in order of increasing complexity; it is perhaps useful to point out here that, in general, the simpler the control system the more skilled the operator needs to be. All of the systems listed have been proved in practice. The control methods for pressure gas entraining air are, in general, similar to those for air blast systems in which the gas is governed to atmospheric pressure. It was, therefore, decided that separate consideration of these was not necessary.

(1) Manual Control of Throughput

(a) Basic Air Blast System

A diagram of the basic air blast burner system is shown in Figure 3, and, since all other systems are developed from this, its operation will be considered in some detail.

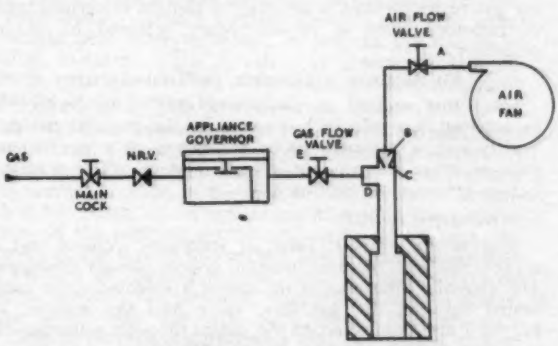


FIGURE 3.—*The Basic Air Blast Burner System.*

Air is supplied to the burner by a suitable fan and the air flow can be adjusted by means of valve (A). The jet of air issuing from the air nozzle (B) in the injector (C) entrains gas, which enters the injector at (D), and the mixture flows along the mixture tube and is burnt in a refractory tunnel. Gas for the burner is governed to a constant pressure by an appliance governor, and the actual flow of gas to the burner can be controlled by means of valve (E).

A non-return valve is fitted into the gas line, as this is a statutory requirement for all air blast systems and is intended to prevent air from flowing into the gas main should the burner exit become blocked. In some cases, it might be desirable to fit an additional non-return valve in the air line to prevent gas from flowing into the fan casing.

The throughput of the burner is largely controlled by the air flow valve. However, since the gas is supplied at a few inches w.g., when the throughput is changed appreciably the gas control valve will also require adjustment if the optimum air : gas ratio is to be maintained.

(*b*) *Improved System*

The disadvantage of having to adjust two valves may be overcome by reducing the gas supply to atmospheric pressure by means of a zero governor fitted as shown in Figure 4. In this system, the air : gas ratio is adjusted by means of the valve (F) positioned between the zero governor and the injector; once set, the ratio will remain reasonably constant whatever the air flow rate. The burner throughput can then be adjusted as required simply by means of the air flow valve.

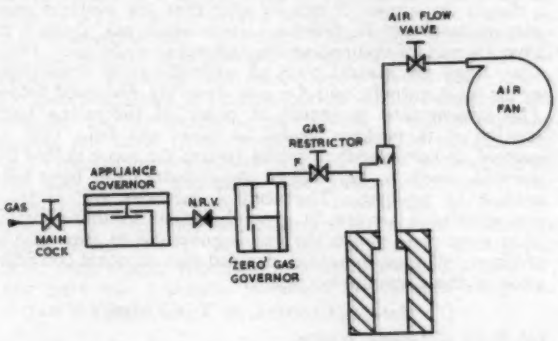


FIGURE 4.—*Improved Air Blast Burner System.*

The mixture setting valve (F) may be conveniently called the gas restrictor and is an integral fitment in certain types of injector, when it is sometimes referred to as an obturator.

(2) AUTOMATIC CONTROL OF THROUGHPUT

Since this section is concerned only with control of throughput, no reference is made to the method of ignition, which is assumed to be by means of a permanent-pilot or other independent ignition system. (For practical burner schemes see Section VII.)

(*a*) *On—Off Control*

This is the simplest form of automatic control and is comparable with the basic manual system already described. The essential difference is the use of a solenoid valve positioned between the gas flow valve and the injector of Figure 3 and connected to the mains through a thermostat or other process control switch. Obviously, a source of re-ignition is required in this type of control.

In some cases, for example, if it is required to maintain an enclosure at a particular temperature, it might be undesirable, from the point of view of efficiency, to allow the flow of cold air into the enclosure during the " off " period. In such a case, the system shown in Figure 3 could still be used, but solenoid valves would need to be fitted into both the gas and air supplies.

(*b*) *High—Low Control*

On-off control can result in large temperature changes that might be undesirable, and, also, re-ignition might be difficult to arrange. High—low control, which overcomes both of these, can be obtained by fitting a weep relay valve in series with the air flow valve in the system shown in Figure 4. However, if the weep relay valve is fitted with both high and low stops then the air flow valve can be dispensed with. The relay valve may be actuated either by a direct-acting thermostat for low-temperature applications or, for high-temperature applications, by an indirect-acting thermostat, e.g., by a thermocouple through a controller switch to a solenoid valve connected to the weep line.

Since high—low control is, perhaps, the most widely used, it is worth considering here other possible valve arrangements that can provide this form of control. In general, high—low flows can be obtained by means of either a solenoid and by-pass or a high—low valve in both the air and gas supplies. Combinations of these two are definitely undesirable, since their response times are normally quite different. It is also possible for the gas supply to be governed to atmospheric pressure while retaining the types of valve mentioned above for use in the air line. This leaves four control systems, namely : —

(*a*) Solenoid and by-pass on both air and gas.
(*b*) High—Low valve on both air and gas.
(*c*) Solenoid and by-pass on air with atmospheric gas.
(*d*) High—Low valve on air with atmospheric gas.

The application of (*a*) can be useful when it is desirable to have a very rapid response between high and low throughputs, but the adjustment of the various valves and by-passes is rather critical.

High—low valves in both air and gas, as in (*b*), are not recommended, since their opening and closing times have to be accurately matched in order to avoid mixture ratio changes during the changeover period, which could result in burner instability or blow off.

This leaves, for general applications, systems using atmospheric governing either with a solenoid and by-pass (*c*) or a high-low valve (*d*) in the air supply. The former is suitable where a high speed of response is required, and is easier to set up than (*a*). However, zero governors are slower in operation than solenoid valves, and the mixture ratio varies considerably during changes from low to high (when it goes weak) and high to low (when it goes rich; this might result in blow-off). Method (*d*), i.e., zero-gas with a high—low valve, is the most suitable of the systems, since the speed of response of a high—low valve is generally low enough to allow the zero governor to operate satisfactorily.

The choice of high—low valve is dependent upon the air pressure it has to handle and the pressure drop that can be afforded. Weep relay valves have been used in the Gas Industry for many years and are quite suitable for use on air up to a pressure of about 5 lb/ sq. in. However, their pressure drop tends to be high when used with air, and this fact must be borne in mind when sizing them for a particular application. Motorized butterfly valves are more suitable in this respect, but might be too slow in operation when used in an automatic programmed control system. There is thus a need for a butterfly or

other valve having a low-pressure drop capable of operation from high to low in a period of, say, 5 to 10 secs. The development of such a valve would be of value to the Industry.

(c) High—Low—Off Control

An extension of the two-level control described above, is to include in the gas supply a solenoid that can be used for "off" control. This, in effect, gives three-level control that may be operated in either of two ways. Figure 5 shows the arrangement applicable to both of these. One method of usage that applies when reignition is available is to use one thermostat for high—low control, and the second thermostat for low—off. The temperature settings of the thermostats can be made quite close together, thus giving better control when load changes are made.

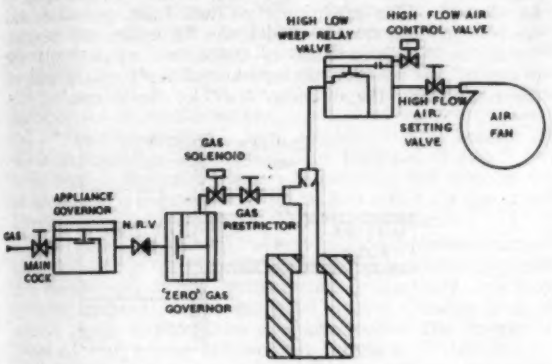


FIGURE 5.—*Air Blast Burner with High—Low—Off Control of Throughput.*

When re-ignition is not available, it is often useful to employ the second or "off" thermostat as an overriding limit control. This shuts off the burner if the low throughput is too high. The difference between this method and the one described above is that, since reignition is not available, a "no-volt trip" (not shown in Figure 5) must be included to prevent the gas solenoid from opening once it has been closed. This can be accomplished by using an automatic control unit as shown in scheme 6 of section VII.

(d) Proportional Control of Throughput

The systems mentioned above provide abrupt changes in throughput when their control switches (thermostats) are operated. There are cases where this is undesirable; for example, in installations of low thermal capacity, where abrupt changes in throughput can cause large fluctuations in temperature. A method of overcoming this difficulty is to control the throughput by relating it to temperature. In practise, the throughput is proportioned according to the deviation of the temperature from the desired value, and so this is called "proportional" control. For this system to operate satisfactorily, an atmospheric-pressure gas governor must be used, otherwise the air : gas ratio might not remain constant. A suitable scheme is shown in Figure 6, in which the air flow valve is positioned by a signal from a suitable proportional controller.

An extension of this control scheme where large load changes result in poor control is to use a proportional plus integral type of controller that will correct for the deviation (offset or droop) of the controlled temperature from that desired. Finally, where an oscillatory condition of the control cannot be satisfactorily corrected by normal

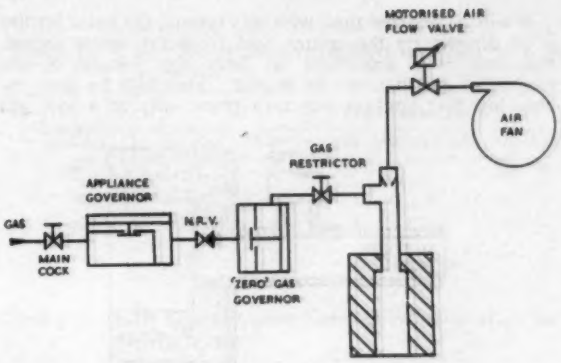


FIGURE 6.—*Air Blast Burner with Proportional Control of Throughput.*

adjustment, the addition of a rate function may be desirable. These features are part of the controller and do not affect the scheme shown in Figure 6. Manufacturers are usually able to advise on the type of controller best suited for a particular application.

V BURNER IGNITION

The most usual and obvious way to ignite gas or mixture issuing from a burner is by means of a flame positioned downstream of the burner exit. This can be by means of a temporary torch or permanent pilot, and in the latter case a spark or glow plug may be used for the electrical ignition of the pilot flame. However, with some types of tunnel burner, this method of ignition can be difficult and even impossible either because of high-temperature applications or because of the difficulty of establishing the flame in its normal position inside the tunnel.

For these reasons, some other method of lighting tunnel burners is required. One method of lighting these burners is to utilize the negative pressure existing in the sudden enlargement zone of the combustion chamber prior to ignition. If a suitable access hole is provided, an ignition flame can be applied and this will be drawn in to light the main flame. Since a positive pressure may now exist, the access hole must be closed to prevent the escape of burning mixture. This is often an awkward task to perform manually, and is very difficult when automatic operation of the burner is required.

Since ignition downstream of, or at, the normal flame position has its limitations, the only remaining method is to ignite the mixture upstream and carry the flame forward to its normal position in the tunnel. This may be accomplished by means of an igniter positioned in the parallel section of the mixture nozzle and arranged so that disturbance to the flow is minimized. Initial experiments with this method of ignition showed that, in many instances, reliable ignition was possible. Figure 7 shows a tunnel burner fitted with this type of ignition. Further, since the method may be incorporated into the burner design, it removes the installation difficulties associated with the choice and correct siting of pilot flame, *etc.*

It will be realized that, with this system, the main burner is lit directly by the igniter, and from the safety aspect, therefore, it is important to limit the volume of uncontrolled gas that can be passed. This may be done by ensuring that ignition can take place only at a low gas

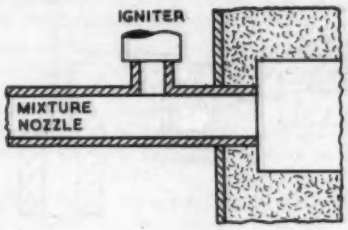


FIGURE 7.—*Tunnel Burner with an Igniter Fitted in the Mixture Nozzle.*

rate or by limiting the time during which gas can pass in the absence of a flame. With this system in mind, the Industrial Gas Development Committee has recently broadened its definition of a pilot flame to include the following:—

(*a*) Flame at a low gas rate, burning either at the main burner or a separate pilot burner;
or

(*b*) flame at any gas rate up to the full-on rate, burning at the burner subject to an appropriate ignition time cycle.

In order to satisfy the latter requirement, a fully automatic control unit, with the ignition period controlled to occur within 2 sec, is now commercially available. (See Section III.)

Although the initial experiments showed the ignition system to be basically sound, some individual cases caused difficulty and were not completely reliable in operation. Hence, an investigation was carried out with the object of providing design criteria for reliable ignition.

The problem may be considered in two parts, firstly to establish the type of igniter that, together with its associated components, is most suitable for industrial usage, and, secondly, to determine a position for the igniter so that reliable ignition occurs regardless of burner size and type.

TYPE OF IGNITER

In early experiments on mixture-tube ignition, small glow plug igniters were used with reasonable success. However, the power dissipation of these igniters was only some 6 W and it was found that, even if they were recessed in the mixture-tube wall, reliable ignition could be obtained only at relatively low mixture velocities, due to convective cooling of the plug filament by the stream. Attention was therefore directed towards the use of a high-tension spark igniter, and in the finalized system a 14 mm screened sparking plug, suitable for rugged industrial service, is used. Full details of the recommended high-tension system are included in Section VI of this Paper. Since the power dissipation in the spark zone is some 100 W, the efficiency of the ignition system is much less affected by mixture velocities than was the case with the glow plug. However, for laboratory applications the glow plug is very useful, since, as it is a low-voltage device, its use entails no particular safety requirements such as are necessary with a high-tension system.

IGNITER POSITION

It is obviously desirable to find a general rule for the position of the igniter that will be equally applicable to all types of tunnel burner regardless of how their mixtures are produced. It is therefore necessary to experiment with the burners that are most critical in this respect, and, in order to choose these, it is instructive at this stage to consider the processes that take place during the ignition of a burner fitted with a mixture nozzle ignition system such as that shown in Figure 7. Upon applying a spark, with mixture flowing, the resulting flame will be stabilized at the point of ignition. Due to the combined effects of flame speed and mixture velocity, the flame will both travel forward and spread out as indicated in Figure 8. This flame will usually produce a back pressure higher than that occurring during normal combustion in the tunnel. The magnitude of this back pressure will depend on the extent to which the flame fills the mixture nozzle, and this in turn is dependent upon both the distance "*l*" between the spark and the forward end of the nozzle and the diameter "*d*" of the nozzle.

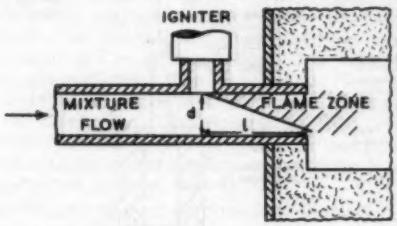


FIGURE 8.—*Flame Zone when Mixture-nozzle Ignition is Applied.*

Thus, the position of the igniter is important where a change in flame back pressure is liable to affect correct burner operation. In practice, this could result either in a sufficient change in throughput to cause lightback or in a significant alteration to the mixture ratio resulting in unreliable ignition. Changes of this nature are not usually apparent where the mixture is produced in a premix machine or when pressure gas/pressure air is employed. However, these effects can be significant where the mixture is produced by means of an air blast injector.

For this reason, investigations have mostly been carried out on air blast systems. Confirmatory checks have been made on burners using other means of producing mixtures; these results are included in Section VI.

The effect of igniter position on the ignition of air blast tunnel burners was investigated by determining firstly for a variety of burners the ranges of igniter positions at which reliable ignition was obtained. Experiments were then carried out to examine the causes of unreliable ignition by studying the variation of mixture ratio when the ignition spark was switched on. Finally, since it is usual to ignite at a low gas rate or turndown condition, the effect of igniter position on reliable ignition at low throughputs was determined for several burners.

(A) IGNITION POSITIONS FOR RELIABLE IGNITION

From the point of view of ignition, it is necessary to classify tunnel burners into two groups, *viz.*, those with parallel injectors and those with venturi injectors, and to treat each group separately.

(i) *Burners with Parallel Injectors*

This group consists of burners with parallel injectors coupled directly to tunnels of various dimensions, i.e.,

M.R.S. types A and B with parallel tunnels, and type C with a converging tunnel. Since the parallel injector is directly coupled to the tunnel, the mixture nozzle is in fact an extension of the same parallel tube as is used for the injector. Therefore, in this type of burner, the mixture nozzle becomes the mixture tube. There is thus a relatively long parallel mixture tube available for the insertion of a suitable igniter. Experiments to find the effect of igniter position on the reliability of ignition have been carried out both with burners operated with a gas pressure of 2 in. w.g. and also with the gas pressure reduced to atmospheric. The experimental procedure adopted in each case was to set the burner controls so that the burner passed the desired throughput with a 4:1 mixture ratio whilst alight, after which the burner was turned off by means of a solenoid valve in the gas supply. When the burner had cooled, the ignition spark was switched on, the gas solenoid was then energized and, after 2 sec, the ignition spark was switched off. A note was then made as to whether or not the burner had lit. This procedure was repeated 10 times for each set of conditions and, if all attempts were successful, "reliable ignition" was obtained. The results of these experiments are tabulated in Tables 1, 3 and 5 for 1 in. type A, B and C burners respectively fed with gas at atmospheric pressure and in tables 2, 4 and 6 for the same burners supplied with gas at 2 in. w.g. pressure.

The results obtained show that ignition becomes increasingly difficult as the distance between the sparking plug and the burner end of the mixture tube is increased, but that reliable ignition can be achieved if this distance is kept within three mixture-tube diameters, when the burner is supplied with gas at atmospheric pressure. If the burner is supplied with gas at 2 in. w.g. pressure, then this distance may be increased to about five mixture-tube diameters before ignition tends to become unreliable.

It is also clear that the results are affected by throughput. The distances given above apply only when the throughput is that given by an air pressure in the range 1 to 3 in. w.g. Where ignition at other rates is required, the distance should be reduced as indicated in the results.

It was thought possible that this distance is limited by the igniter being so close to the air nozzle as to be situated in the region where mixing is incomplete. Experiments were, therefore, carried out on a 1 in. type A burner fitted with a long mixture tube. The results showed that this was not the case, and, therefore, the limitation is imposed by some other effect.

The design data regarding igniter position obtained above were applied to ½ in. and 2 in. sizes of burners, and reliable ignition resulted.

The minimum distance between the igniter and the forward end of the mixture nozzle is normally governed by the thickness of refractory through which the mixture nozzle passes. This thickness does not increase linearly with burner size and thus "d" increases more rapidly than "l". It is, therefore, easier to ignite large burners since

TABLE 1.—*1 in. Type A Burner Supplied with Gas at Atmospheric Pressure.*

Gas Rate (cu. ft/hr)	Air Pressure (in. w.g.)	Plug Position (l/d)							
		0·58	1·39	2·21	3·03	3·85	4·63	5·50	6·32
20	0·2	/	/	/	/	•	•	•	×
50	1·2	/	/	/	/	/¹	/	•	×
100	4·8	/	/	/	/	•	•	×	×
150	10·7	/	•	×	×	×	×	×	×

TABLE 2.—*1 in. Type A Burner Supplied with Gas at 2 in. w.g. Pressure.*

Gas Rate (cu. ft/hr)	Air Pressure (in. w.g.)	Plug Position (l/d)							
		0·58	1·39	2·21	3·03	3·85	4·63	5·50	6·32
20	0·2	/	/	/	/	/	/	/	•
50	1·2	/	/	/	/	/	/	/	/
100	4·8	/	/	/	/	/	/¹	•	•
150	10·7	/	/	/	•	•	•	×	×

TABLE 3.—*1 in. Type B Burner Supplied with Gas at Atmospheric Pressure.*

Gas Rate (cu. ft/hr)	Air Pressure (in. w.g.)	Plug Position (l/d)						
		1·02	2·36	3·72	5·06	6·41	7·76	9·10
10	0·14	/	•	•	×	×	×	×
20	0·54	/	/	•	×	×	×	×
50	3·36	/	/	/	•	×	×	×
100	13·45	/	/	/	/	•	×	×
150	30·2	/	/	/	/	•	•	•

TABLE 4.—*1 in. Type B Burner Supplied with Gas at 2 in. w.g. Pressure.*

Gas Rate (cu. ft/hr)	Air Pressure (in. w.g.)	Plug Position (l/d)						
		1·02	2·36	3·72	5·06	6·41	7·76	9·10
10	0·14	/	/	/	/	/	/	/
20	0·54	/	/	/	/	/	/	/
50	3·36	/	/	/	/	/	•	•
100	13·45	/	/	/	/	/	/	•
150	30·2	/	/	/	×	•	×	×

TABLE 5.—*1 in. Type C Burner Supplied with Gas at Atmospheric Pressure.*

Gas Rate (cu. ft/hr)	Air Pressure (in. w.g.)	Plug Position (l/d)						
		0·7	1·4	2·1	2·8	3·5	4·2	4·9
50	0·78	/	/	•	•	•	×	×
75	1·76	/	/	/	/	/	/	•
100	3·12	/	/	/	/	/	/	•
150	7·02	/	/	/	/	/	•	•

TABLE 6.—*1 in. Type C Burner Supplied with Gas at 2 in. w.g. Pressure.*

Gas Rate (cu. ft/hr)	Air Pressure (in. w.g.)	Plug Position (l/d)						
		0·7	1·4	2·1	2·8	3·5	4·2	4·9
50	0·78	/	/	/	/	/	/	/
75	1·76	/	/	/	/	/	/	/
100	3·12	/	/	/	/	/	/	/
150	7·02	/	/	/	/	/	/	/

/ Reliable ignition.
/¹ One failure in 10 trials.
• Unreliable.
× Unignitable.

their l/d ratios can be made quite small. Unfortunately, this is not the case with small burners, and it is interesting to calculate limiting sizes that can be operated by this form of ignition. If the recommended sparking plug is used, then a distance of at least $\frac{1}{8}$ in. must be allowed between the burner backplate and the central electrode of the sparking plug. Allowing a minimum of $\frac{1}{8}$ in. for the thickness of the backplate and refractory end face gives a value for "l" of 1 in. Assuming three diameters of mixture tube for reliable ignition when using gas governed to atmospheric pressure, the minimum mixture-tube diameter becomes 0·33 in. The burner sizes (i.e., burner exit diameters) corresponding to this are approximately 0·5 in., 0·9 in. and 0·5 in. for types A, B and C respectively.

Similarly, calculations based on five diameters, for burners supplied with pressure gas, give burner sizes of approximately 0·3 in., 0·5 in. and 0·3 in. for types A, B and C respectively. Any sizes below these will obviously require special attention with regard to the position and the type of sparking plug used.

(ii) *Burners with Venturi Injectors*

This group consists of burners with venturi injectors connected sometimes by appreciable lengths of pipe to mixture nozzles; i.e. M.R.S. type D with converging tunnels, and type F with parallel tunnels.

In order to fit ignition to these burners, there must be a parallel portion of mixture nozzle behind the burner backplate, as shown in Figure 9. In practice, it has been found that successful ignition can be obtained if the distance l (shown in Figure 9) is within three diameters of the burner and of the parallel section of the nozzle. An additional diameter of parallel section should be left upstream of the igniter position to avoid the possibility of lightback. In order to ascertain whether or not the same limits of l/d apply to this type of burner as to the parallel-injector types, a special mixture nozzle was prepared having a long parallel portion. The results obtained showed that unreliable ignition occurred at similar l/d ratios, both with atmospheric and pressure gas, as occur with the parallel injector burners. In the case of the F and D burners, unreliable ignition is obviously not caused by direct interaction of flame with the mixing process, and, as with the parallel-injector types, there must be some other reason for the onset of unreliable ignition. This may be explained by the effect of the ignition flame upon back pressure and, hence, mixture ratio. The results show that a burner supplied with pressure gas is less dependent upon igniter position, as would be expected if the back pressure causes the mixture to go too weak for reliable ignition to take place. The effect of igniter position on the mixture ratio was therefore investigated.

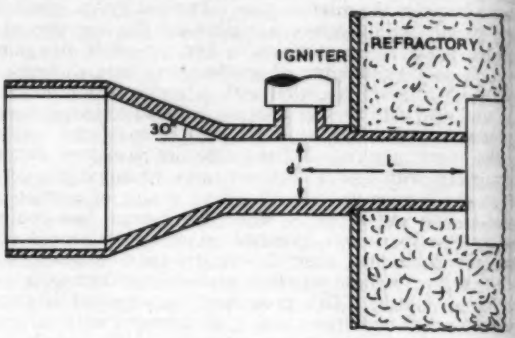


FIGURE 9.—*Igniter Fitted to Extended Mixture Nozzle.*

(B) THE EFFECT OF IGNITER POSITION ON MIXTURE RATIO

Experiments were carried out to determine the changes in mixture ratio resulting from the application of an ignition spark at different positions along a mixture nozzle or tube. The purpose of these experiments was to establish the cause of unreliable ignition and to assist in the further understanding of the process of mixture-nozzle ignition.

The results of the experiments reported in the previous section indicate that burner types F and D show similiar characteristics, regarding igniter position, to those with parallel injectors (types A, B and C) and are, in general, less critical in this respect. Consequently, the experiments were carried out using burners of types A, B and C; most of the work was done with the 1 in. size of burner, but confirmatory checks were carried out on $\frac{1}{2}$ in. and 2 in. type A burners.

The burners were supplied with metered air and gas, the gas being controlled to atmospheric pressure by means of a "zero" governor upstream of a gas restrictor. A solenoid valve was used to provide on—off control of the

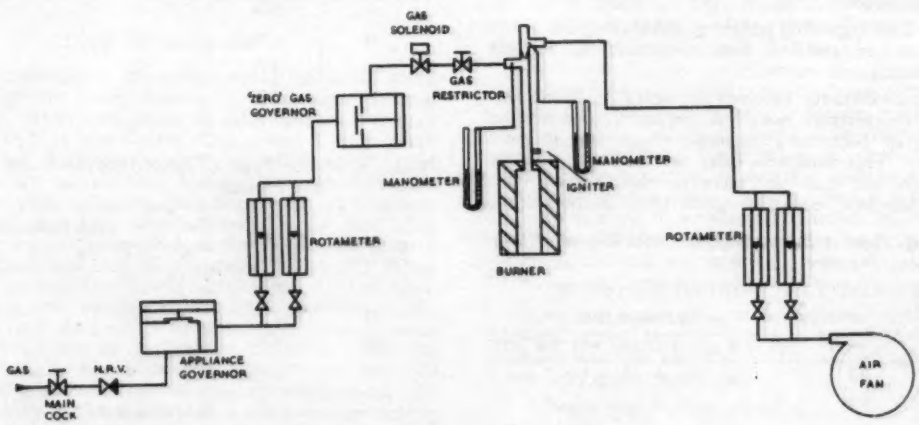


FIGURE 10.—*System for Investigating the Variation of Mixture Ratio with Igniter Position.*

gas supply. A schematic diagram of the experimental rig is shown in Figure 10. The test procedure was similar to that described above, i.e., at each throughput the gas restrictor was adjusted with the burner operating normally, to give an air:gas ratio of 4:1. The mixture ratio was then measured when an ignition spark was applied at various positions along the mixture tube, and, for each burner, a series of results were obtained at various throughputs.

Figures 11(*a*) (*b*) and (*c*) show the variation in mixture ratio with igniter position for 1 in., types A, B and C burners respectively at a series of throughputs with the gas supplied to the burner at atmospheric pressure. Figures 11(*d*) and (*e*) show the results obtained with ½ in. and 2 in. type A burners respectively, under the same conditions.

A similar series of experiments was carried out using gas at 2 in. w.g. by removing the atmospheric (zero) governor from the scheme shown in Figure 10. These results are shown in Figures 12(*a*), (*b*) and (*c*) for 1 in., types A, B and C burners respectively, and in Figures 12(*d*) and (*e*) for ½ in. and 2 in. type A respectively.

The results show that, in general, the mixture ratio does go weak both with increasing distance between the igniter and the end of the mixture tube and with decreasing throughput. These two facts substantiate the concept of the processes occurring during ignition presented earlier since the effect of the back pressure due to the ignition flame will be greater with increasing l/d and/or decreasing mixture velocity.

Experiments have shown that the burners used will operate satisfactorily with air/gas ratios in the range 8:1 to 10:1. These ratios show that ignition should take place with quite large values of l/d if the mixture ratio, as measured above, is considered. The experiments described

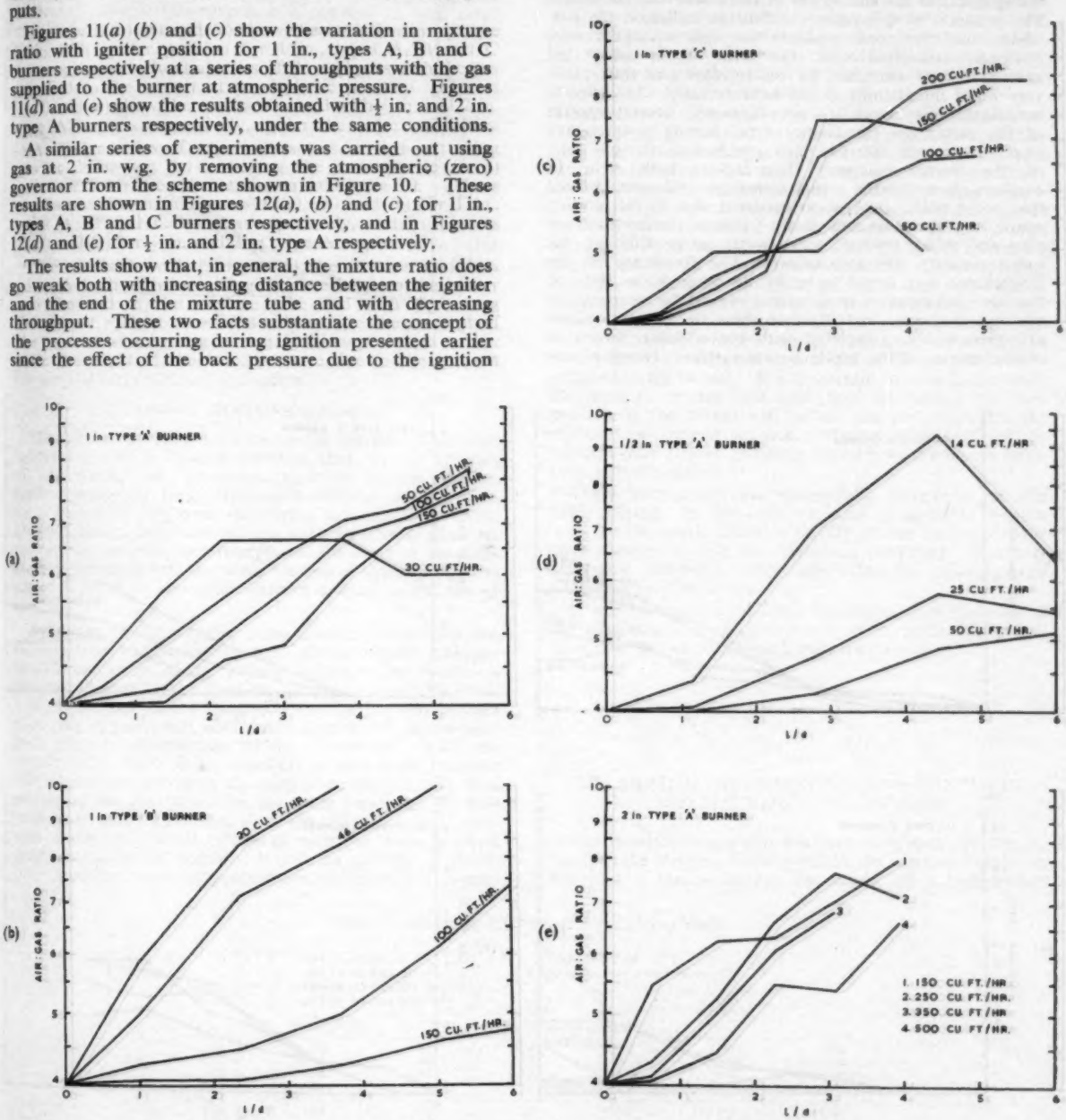


FIGURE 11.—*The Variation of Mixture Ratio with Igniter Position, Using Gas at Atmospheric Pressure.*

in the previous section show that this is not the case and, therefore, there must be some other factor influencing the ignition process to cause unreliable ignition.

During the course of the above experiments, it was noticed that there was a noise or "roughness" in the combustion produced when the spark was applied. This noise became more pronounced as the distance between the igniter and the end of the mixture tube was increased. The presence of this noisy combustion indicated the possibility that the rapid pressure fluctuations, which were obviously associated with the noise, could affect the amount of gas entrained by the injector and thus cause very rapid fluctuations in the mixture ratio. In order to investigate this possibility, an electronic pressure gauge of the diaphragm-capacitance type, having a frequency response to over 200 c/s, was attached to the gas inlet of the burner injector. Observations both with an oscilloscope and with a high-speed pen recorder showed that when noisy combustion occurred, due to the ignition spark, the instantaneous static pressure varied between plus and minus several inches water gauge although the mean pressure was atmospheric. The frequency of the fluctuations was found to be in the range 50 to 100 c/s. Further quantitative experiments would be required to evaluate the cause and effect of these fluctuations, which are, presumably, associated with the acoustic resonance characteristics of the whole burner system. However, the pressure measurements indicate that, even if the air:gas ratio of the mixture is, say, 6:1 as measured, the instantaneous ratio may go outside the range of ignitable mixtures. This could well be the reason for unreliable ignition occurring although the measured air:gas ratio is within this range.

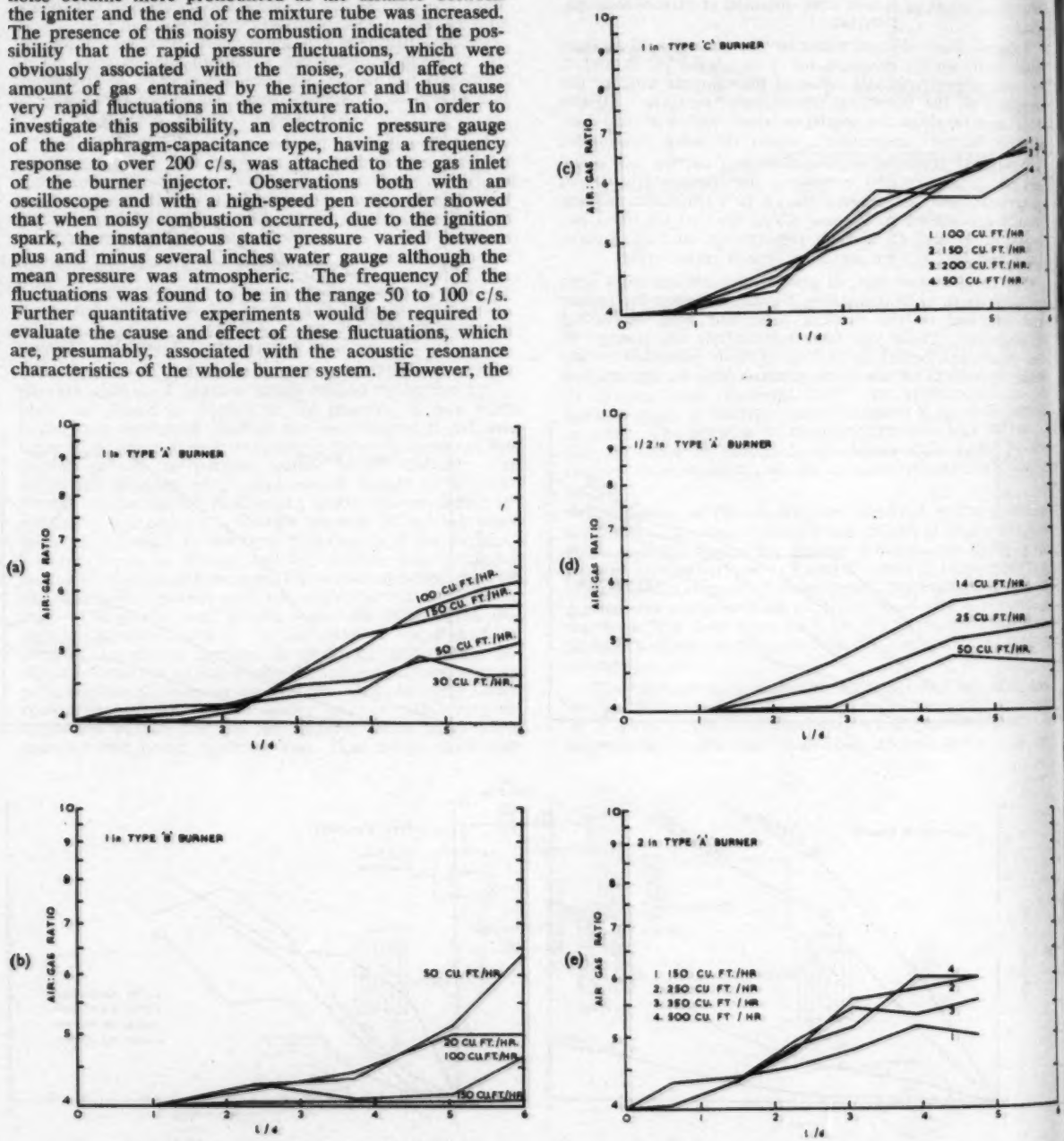


FIGURE 12.—*The Variation of Mixture Ratio with Igniter Position Using G s at 2 in. w.g. Pressure.*

(c) The Effect of Igniter Position at Low Throughputs

The minimum throughput of a tunnel burner is usually determined by that rate of flow at which the flame lights back down the mixture nozzle, and this may be influenced by local flow conditions. When mixture-nozzle ignition is applied, some flow disturbance will obviously be produced and, since it is sometimes necessary to ignite a burner at its lowest possible throughput, it is essential in such cases that this disturbance should not cause the burner to light back.

Experiments have, therefore, been carried out to investigate the effect of mixture-nozzle ignition upon burners passing low throughputs. Table 7 shows the types and sizes of burner examined, and the instability regions determined by Francis and Hoggarth[2] are given for each burner. Since the minimum flow rates likely to be used in practice are difficult to define precisely, the actual flow rates shown were chosen to be below these minimum rates, and the approximate value of the air pressure at the burner air nozzle is given in each case. In all the experiments reported in Table 7, reliable ignition was achieved up to the l/d ratios given.

These results show that there is a further restriction upon the minimum l/d ratio of 3 previously given, if reliable ignition is required at the lowest possible flow rates when using gas at atmospheric pressure. However, if gas is supplied at 2 in. w.g. pressure, then the maximum value of 5 for the l/d ratio remains applicable.

UNLIT MIXTURE RATIO

During the experimental work on the ignition of air blast tunnel burners, it became obvious that, in the absence of any flame, and, therefore, regardless of the ignition method employed, the mixture ratio could be gas-rich often by a factor of two over its normal stoichiometric value. Under certain conditions, this can have an adverse effect on the ignition process, and it explains also some of the difficulties associated with the usual method of igniting air blast tunnel burners by the application of a flame to the tunnel exit.

The cause of the mixture being gas-rich when unlit can be explained by considering the various pressure changes in different parts of the burner system. The burner is designed to pass a mixture of the correct air : gas ratio when it is alight, and in this condition the combustion process occurring in the tunnel contributes appreciably to the total back pressure downstream of the air nozzle. With the burner unlit, there is a reduction in this back pressure that appreciably increases the suction on the gas inlet, thus increasing the gas flow. On the other hand, the air flow remains virtually unaltered, since the change in back pressure is relatively small compared with the static pressure drop across the air nozzle. A gas-rich mixture is, therefore, produced, and the proportions of which will depend upon the actual design of the burner. The calculated air : gas ratios for unlit mixtures are 1·02 : 1, 2·89 : 1 and 1·17 : 1 for burners of types A, B and C respectively.

The detailed calculation of these values is given in Appendix 1, but it must be remembered that the calculations are based on the assumption that an air : gas ratio of 4 : 1 is obtained with gas supplied at atmospheric pressure to the injector inlet. In practice, the burner is designed to give a slightly rich mixture using gas governed to atmospheric pressure, and a restricting cock is provided to adjust the mixture ratio. However, the calculated values show that it may be possible, under certain conditions, to have an unlit mixture that is very gas-rich.

Experiments on several type A burners have shown that, if the burner is adjusted to operate on a 4 : 1 air : gas mixture with atmospheric gas inlet pressure, the unlit mixture ratios lie between 1·2 : 1 and 2 : 1 and are, therefore, above the upper limit of inflammability. It is interesting to consider how this type of burner is lit successfully in practice by the application of a flame to the tunnel exit. To start with, air only is flowing, so that after the gas is turned on there is bound to be a zone of ignitable mixture passing through the tunnel. If this zone has a sufficient time of residence in the tunnel, and if the throughput is low enough, the ignition flame causes the main flame to light back and stabilize in the tunnel. The pressure conditions then become normal and so mixture of the correct ratio is supplied to the burner. It is important to note that, should the main flame not light back into the tunnel, the back pressure in the burner will be too low and, therefore, the mixture will remain gas-rich. Manual adjustment of the mixture ratio is then required in order to produce a lightback into the tunnel.

These burners are also successfully ignited by mixture tube ignition. In this case, the zone of ignitable mixture is lit by the spark and this rapidly causes an appreciable back pressure so that the mixture is weakened. The mixture ratio, therefore, never approaches the values quoted above for unlit mixtures.

It will be appreciated from these two cases that one of the advantages of mixture nozzle/tube ignition is that it does not rely on a lightback into the tunnel.

VI DESIGN INFORMATION FOR MIXTURE-NOZZLE IGNITION SYSTEMS

The ignition system that has been developed operates by igniting the mixture flowing within the mixture nozzle (or tube) of a tunnel burner by means of a high-tension

TABLE 7—*Reliable Ignition at Low Throughputs.*

Burner Type and Size	Lightback Rate (cu. ft/hr)	Burner Normally Unstable Below :— (cu. ft/hr)	Reliable Ignition Achieved at :—			
			Gas Rate (cu. ft/hr)	Air Pressure (in. w.g.)	l/d within :—	
1 in. A	17	35	20	0·2	3·03	Gas supplied at atmospheric pressure.
1 in. B	4·5	10	10	0·14	1·02	
1 in. C	24	55	50	0·78	1·4	
2 in. B	26	60	40	0·14	1·7	
1 in. A	17	35	20	0·2	5·5	Gas supplied at 2 in. w.g. pressure.
1 in. B	4·5	10	10	0·14	9·10	
1 in. C	24	55	50	0·78	4·9	
2 in. B	26	60	50	0·14	7·42	

spark. This system relies on the fact that the flame is not normally stable in this position, but is swept downstream into the tunnel by the flowing mixture when the ignition spark is switched off. Figure 13 shows a schematic diagram of a tunnel burner fitted with a spark igniter in the mixture

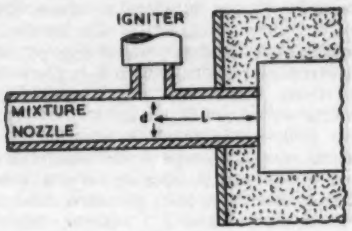


FIGURE 13.—*Tunnel Burner Fitted with a Spark Igniter.*

nozzle. The ignition system consists of a sparking plug, high-tension lead, and ignition transformer. Each of these components must be selected as suitable for rugged industrial service, and the following equipment supplied by Lodge Limited, of Rugby, can be recommended:—

Sparking plug, 14 mm type S.R.L. 14.

High-tension Cable, EV.1388 Figure 2. Spec. 110. (Length as required, but normally 3 ft. or 6 ft.)

High-tension Transformer, input 200 to 250 V, 50 cycles; output 10,000 V to earth fitted with a BC 5 outlet connexion.

A photograph of these components is shown in Figure 14. The assembled system, as it appears when fitted to a tunnel burner, is shown by the photographs in Figure 15. It will be evident that the outer screening of the high-tension lead forms the earth return conductor from the plug to the transformer. This feature is of particular importance, since it avoids both the necessity of providing a separate return conductor and the possibility of danger arising from the use of a two-conductor system.

As far as is known, the recommended components are the only ones at present commercially available to provide this facility and, consequently, increased safety in practice.

The use of a 10 kV system enables the earth electrodes, normally fitted to the sparking plug, to be removed so that the spark occurs between the central electrode and the body of the plug, and this offers the following advantages:—

(1) The plug may be positioned flush with the wall of the mixture nozzle (or tube), so that less disturbance to flow is produced.

(2) There is no need to check the spark gap.

(3) Since the effective gap is large, there is less risk of fouling up.

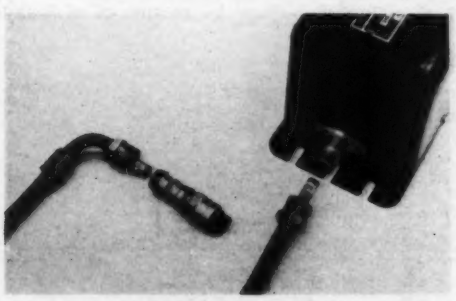
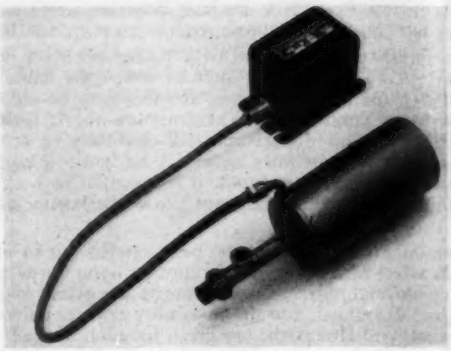
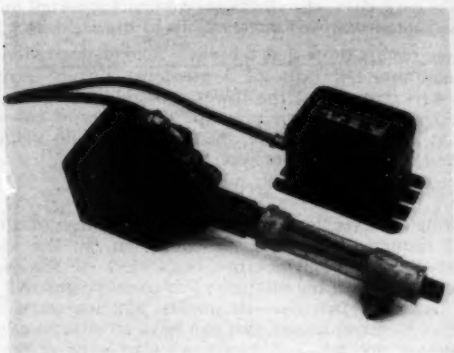


FIGURE 14.—*Components of the Ignition System.*



(a)



(b)

FIGURE 15.—*The Ignition System Fitted to an Air Blast Tunnel Burner (a) with parallel injector, and (b) with venturi injector that may be remote.*

Figure 16 shows the modification required, and this is simply and conveniently carried out in a small lathe. Also shown in Figure 16 is a dimensioned drawing of a suitable sparking plug boss welded onto a mixture nozzle (or tube). This arrangement has been found suitable for burners with mixture nozzle/tube diameters in excess of about $\frac{1}{4}$ in. For burners having mixture nozzles/tubes smaller than this, the sparking plug modification and boss assembly should be as shown in Figure 17. Burners with mixture-nozzles/tubes below $\frac{5}{16}$ in. diameter will require special attention.

SPARKING PLUG POSITION

The sparking plug should be fitted as close to the burner tunnel as possible and the mixture nozzle/tube between the plug and tunnel must be parallel or diverging, with no obstructions to disturb the flow pattern. If the flow is disturbed, then the process of ignition may cause the flame to be stabilized within the mixture nozzle/tube and so cause damage to the burner by overheating.

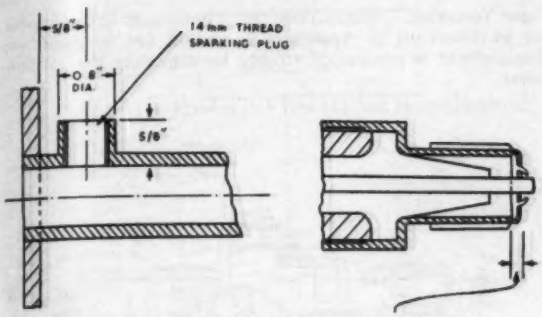

5/8"
14 mm THREAD
SPARKING PLUG
0·8" DIA
5/8"
Machine off this portion of plug to the inner step ; this is also level with the end of the thread. After the machining operation, remove the end of the central electrode so that it is level with the front face.

FIGURE 16.—*Sparking Plug Modifications and Mounting-boss Details for Mixture Nozzles / Tubes Larger than ½ in. i.d.*

If the above conditions are complied with, then, in the majority of cases, reliable ignition will result regardless of burner type or of the method whereby its mixture is produced. However, in the smaller sizes of burner, say those with mixture nozzles/tubes with diameters below about 1 in., the position of the sparking plug must be given closer attention. The most important factor requiring consideration, is the ratio of $l:d$ shown in Figure 13.

(A) AIR BLAST TUNNEL BURNERS

The maximum values of l expressed in terms of d are:—

(i) Air blast tunnel burners supplied with gas at atmospheric ("zero") pressure must have l not greater than $3d$.

(ii) Air blast tunnel burners supplied with gas at a pressure not below 2 in. w.g. must have l not greater than $5d$.

In the case of integral burners (that is, those with a parallel injector coupled directly to a tunnel), the mixture nozzle is the mixture tube, and when this type of burner is being designed it is important to allow sufficient distance between the sparking plug and the air nozzle for the completion of the mixing process. This condition is generally complied with if the ratio of this distance to the diameter of the mixture tube is about 7 to 8.

Air blast tunnel burners with multiple mixture nozzles/tubes may have the igniter positioned in only one tube, and in this case the l/d ratio is not as critical as with burners having a single mixture tube.

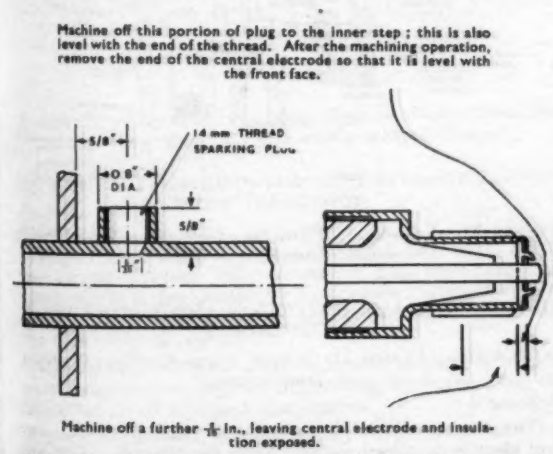

Machine off this portion of plug to the inner step ; this is also level with the end of the thread. After the machining operation, remove the end of the central electrode so that it is level with the front face.
5/8"
14 mm THREAD
SPARKING PLUG
0·8" DIA
5/8"
Machine off a further 1/16 in., leaving central electrode and insulation exposed.

FIGURE 17.—*Sparking Plug Modifications and Mounting-boss Details for Mixture Nozzles/Tubes between ½ in. and 5/16 in. i.d.*

(B) OTHER BURNERS

It has been shown that air blast burners are the most critical in respect of sparking-plug position and, therefore, in general, the limiting values of l given above may be applied with confidence to other burners.

In particular, the following results have been obtained for premix burners of the following types:—

(i) Tunnel burner fed from a premix machine. Ignition very satisfactory up to an l/d ratio of 7; no results available beyond this value (i.e., this was not a limit).

(ii) Non blow-off tip (West Midlands Gas Board type) with fixed l/d ratio of 1·5. Successful ignition resulted both with premix and air blast.

(iii) Modified commercial type of burner nozzle firing into a tunnel. (K.B. type 55 with parallel portion extended and with the heat-resisting steel ring made flush instead of protruding.) Fixed l/d ratio of 3·5. Ignition successful both with premix and air blast.

The information given above enables mixture nozzle ignition to be applied to various types of burner, and practical burner systems incorporating this type of ignition are presented in Section VII.

VII BURNER CONTROL SYSTEMS

In industrial practice, various combinations of safety, ignition and throughput control may be required. The integration of two or more of these functions can be complicated by the interaction between them. Consequently, the following integrated burner control systems are given.

The order of presentation is based on the assumption that some means of controlling throughput is always required. Ignition is first added to throughput control, which may be either manual or automatic. Thus, ignition with manual throughput control is given in schemes 1 and 2, and with automatic throughput control in scheme 3. Flame protection added to throughput control is not considered, since in practice flame protection would seldom be used without ignition. However, should this be required, then ignition can be omitted from schemes 4, 5 and 6. Finally, ignition and flame protection with throughput control is presented, schemes 4 and 5 giving manual throughput control and scheme 6 automatic throughput control.

The choice of a particular system depends on the detailed requirements of the installation under consideration and, consequently, is not dealt with here. In connexion with this choice, it is important that the distinction between semi- and fully-automatic control units should be clearly understood.

Where it is required to fire a burner into an enclosed space under conditions such that an explosion might occur, controlled ignition should be used, and this is provided only in a fully-automatic programme control unit (e.g.,

"Elcontrol" type SPL164 or FST2). Examples of the use of this are given under schemes 4, 5 and 6. In some cases, it may be permissible to release gas/air mixtures from a burner into a large free space, as might be the case in a local heating application. If this is so, then it might not be necessary to fit a "flame-protection device" to ensure safe lighting-up procedure. However, it might be desirable to leave a burner running unattended, in which case flame failure must be guarded against. The installation may also call for the use of certain interlocks so that the burner will shut down if any one of those operates (i.e., gas or electricity supply failure, air failure, pressure limit, thermostat limit, conveyor trip switch, *etc.*) The use of a semi-automatic control unit ("Ether" Model 700, "Elcontrol" FST1) can then be specified, but, since these do not provide a controlled ignition period, they should not be fitted where this is required. Systems using a semi-automatic unit are also given under schemes 4, 5 and 6.

In order to limit the amount of air/gas mixture that it is possible to release, should a fault occur, it is desirable to ignite all burners, whether manually or automatically controlled, at a low rate, and this should be arranged wherever possible. A brief description of setting-up procedure is included in Appendix 2.

IGNITION WITH THROUGHPUT CONTROL

(A) Manual Throughput Control

Scheme 1

This scheme provides for "press-button" ignition with throughput controlled manually by adjusting the air flow valve, and is shown in Figure 18. The scheme has the merit of simplicity and the few components required result in a relatively inexpensive installation.

Its disadvantages are:—

(*a*) A trained operator is required for starting and running the burner, as with torch ignition.

(*b*) For lighting up at low flow and when adjusting throughput over a wide range by means of the air flow valve, the gas valve has also to be adjusted in order to keep the mixture ratio within reasonable limits.

(*c*) This system should only be used where manual lighting up is allowable (e.g., local heating in the open).

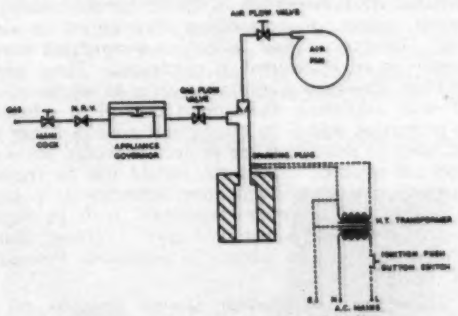


FIGURE 18.—*Scheme* 1, *Providing Ignition and Simple Manual Throughput Control.*

Scheme 2

The disadvantage of having to adjust two valves for throughput control is overcome in this scheme by the use of a "zero" or atmospheric governor in the gas line, as shown in Figure 19. Here the gas flow valve is termed a "gas restrictor" (sometimes an "obturator"), and, once set as described in Appendix 2, should not be disturbed. Throughput is controlled simply by adjusting the air flow valve.

Limitations as for (*a*) and (*c*), scheme 1.

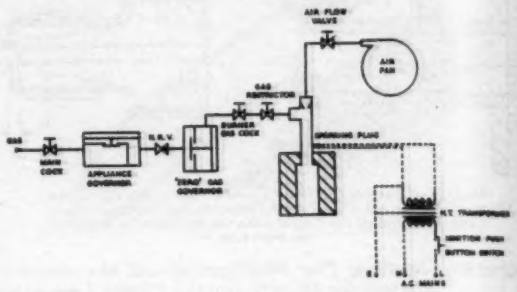


FIGURE 19.—*Scheme* 2, *Providing Ignition and Improved Manual Throughput Control.*

(B) Automatic Throughput Control

Scheme 3

Where thermostatic control is desired, this may be achieved by including a high-low valve in the air line of Scheme 2. This is shown in Figure 20, in which a weep relay valve is shown. Where pressure losses are too high, a motorized butterfly valve may be used in its place. The choice of valve for this purpose is discussed in greater detail in Section IV of this paper.

This scheme may be extended to include proportional throughput control by using a suitable valve in place of the high-low valve in Figure 20. Here, again, further information is given in Section IV.

Limitations as for (*a*) except when running and (*c*), scheme 1.

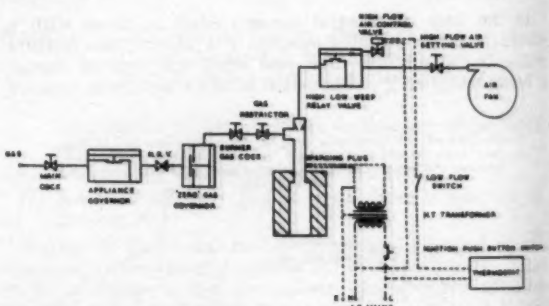


FIGURE 20.—*Scheme* 3, *Providing Ignition with Automatic Throughput Control.*

IGNITION, FLAME DETECTION AND THROUGHPUT CONTROL

(A) Ignition, Flame Detection with Manual Control of Throughput

Scheme 4

The choice of semi-automatic and fully automatic control units is discussed above. Since the schemes differ only in internal wiring, Figure 21 is applicable to both units.

Limitations as for (*a*) and (*b*), scheme 1; where semi-automatic control is used, then for (*c*) as scheme 1.

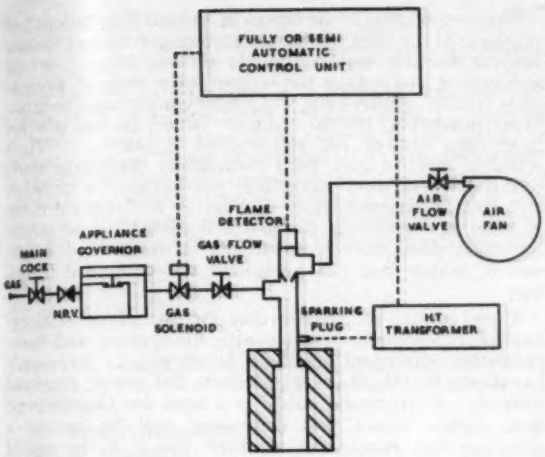


FIGURE 21.—*Scheme 4, Providing Ignition, Flame Protection and Simple Manual Throughput Control.*

Scheme 5

Where ease of throughput control is important, a zero governor can be used with either control unit. This is shown in Figure 22. A variation of this is on—off control of throughput using a thermostat to operate the fully automatic unit.

Limitations as for (*a*), scheme 1; where semi-automatic control is used, as for (*c*), scheme 1.

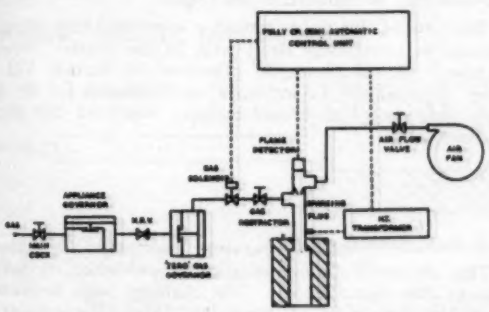


FIGURE 22.—*Scheme 5, Providing Ignition, Flame Protection and Improved Manual Throughput Control.*

(B) IGNITION, FLAME DETECTION WITH AUTOMATIC CONTROL OF THROUGHPUT

Scheme 6

High—low control is shown in Figure 23. Here, again, the choice between fully automatic and semi-automatic control units is determined by the considerations referred to above. Thermostatic control can be arranged to operate the high—low air valve.

Limitations:—Where semi-automatic control is used, a trained operator is required for starting the burner, and the limitation (*c*) of scheme 1 also applies.

Since this scheme, using the fully programmed unit, has a wide application, a brief description of a suitable programme is included.

(*a*) Start, either by push-button or process interlock. Fan starts. Purge period at high-flow air rate regardless of thermostat position. Safe-start check of flame detector.

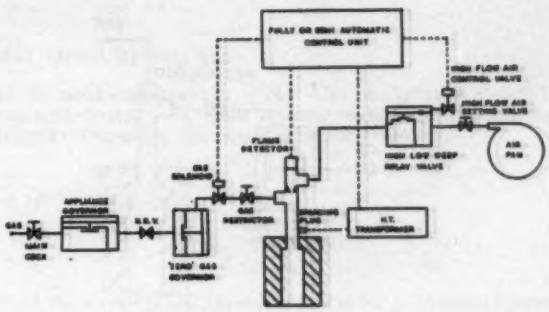


FIGURE 23.—*Scheme 6, Providing Ignition, Flame Protection and Automatic Throughput Control.*

(*b*) Low-flow air rate prior to ignition sequence.

(*c*) Spark-on, gas-on.

(*d*) Gas off, spark off, 2 sec after (*c*) unless flame is established; a low-fire stabilizing period then follows.

(*e*) The high-fire valve is now operated and control of high—low rate can now proceed.

(*f*) Upon flame failure, the gas is shut off and an alarm operated, followed by a short post-purge period.

(*g*) The fan is switched off, and the unit can only be restarted by depressing a re-set button.

No times have been included, since these can be varied to suit various motor and cam arrangements. The critical timing is between steps (*c*) and (*d*), i.e., the gas-on timed interval, which should be kept to a minimum, but must be long enough to ensure reliable ignition; in practice, 2 sec is a suitable compromise.

An additional thermostat may be fitted to scheme 6 to provide either high-temperature limit shut-down or high—low—off control. The choice of high—low air valve is discussed in Section IV of this paper, as also is the use of a proportional control valve where continuous control of throughput is required.

Due to the lack of suitable control equipment, it has not been possible to apply full programming to multi-burner installations other than by using individual control units.

CORRECT POSITION OF MAIN GAS SOLENOID VALVE

The importance of the correct position of the main gas solenoid valve became apparent when investigating one or two early applications of programmed ignition that were giving trouble.

The systems were used on an automatic ignition cycle of 2 sec and it was found that the transient response of zero governors was the cause of rich blow-off. This is explained by considering the operation of the system shown in Figure 24. Before the gas solenoid valve (V) is opened, there will be a negative pressure in the gas pipe (P). This will have the effect of fully opening the zero governor (Z). Upon energizing valve (V), a very rich mixture will be produced during the time that the governor (Z) takes to operate correctly. Rich blow-off can, therefore, occur, since the ignition back pressure lasts only for a short period of time that may be less than the response time of the zero governor.

The response time of the zero governor is put to good effect if the solenoid valve is fitted as shown in Figure 25. Here there will be a positive pressure in the pipe

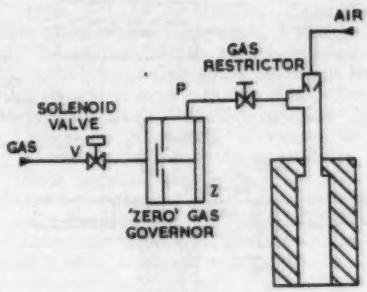


FIGURE 24.—*Incorrect Position for Solenoid Gas Valve when used with a "Zero" Governor.*

(P) tending to close the zero governor (Z). Upon energizing valve (V), the resulting mixture will be very weak, but the negative pressure created by the injector decreases considerably the time of response of the governor. This method of operation avoids the possibility of a rich mixture being produced that could result in a blow-off. It is, therefore, important that the solenoid valve (where used) should be positioned as shown in Figure 25, and all schemes given in this paper conform to this.

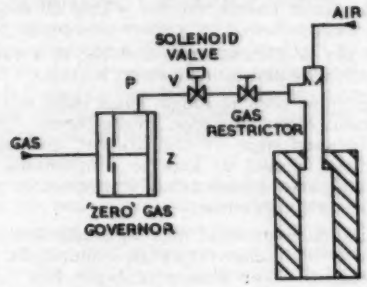


FIGURE 25.—*Correct Position for Solenoid Gas Valve when used with a "Zero" Governor.*

Particular attention is drawn to the fact that some mixture controllers have a zero governor and injector coupled together, and these must be separate when used with automatic ignition controllers so that a solenoid valve can be positioned between them.

VIII CONCLUSIONS

The method of electrical ignition devised for tunnel burners and developed into a suitably rugged form for industrial use has proved its reliability in numerous installations.

The flame protection required in some of these cases, either for unattended operation or for automatic programmed ignition, was obtained by developing an electronic flame-detector circuit to operate on tunnel burner flames, together with a suitable programme controller. Suitable units are now commercially available and, in fact, have been in use for some time.

Since experience in the design of various installations had emphasized the need for burner throughput control systems suitable for use with automatic process control, several methods of controlling throughput were devised. Because these usually require integrating with ignition and, possibly, flame protection, several complete burner control schemes have been worked out and proved in practice. These schemes have, in fact, been successfully applied to many tunnel burners used industrially on consumers' premises and with throughputs ranging from 70 to 7,000 cu. ft/hr. of town gas. Although the practical difficulties are greater for small sizes, there is apparently no upper limit to the size of burner that can be ignited and controlled in this way.

These control schemes involve the use of conventional control components together with the ignition and flame protection equipment described in this paper. Experience has shown that there are requirements for new or improved controls. In particular, there is a need for improved air flow control valves, and there may well be use for a governor that enables an air blast burner to be ignited with gas at about 2 in. w.g. pressure and then to operate with gas at atmospheric pressure.

It appears also that there is a demand for flame-protection systems that can be applied economically to multi-burner installations. In this connexion, when the cost of fitting flame protection is assessed it should be related to the gas consumption of the burner. Since large air blast burners are now available, the relative cost of flame protection can be small. The existence of these burners sometimes enables the number of burners used on an installation to be very considerably reduced. Consequently, the importance of the demand for the flame protection of multi-burners may be reduced in the future.

The title of this paper covers a wide field that obviously cannot be completely dealt with in the paper. While it is hoped that the material presented in Section VII will cover the majority of industrial requirements for the ignition and control of tunnel burners, work on this subject is continuing.

Acknowledgments

This *Research Communication* is published by permission of The Gas Council. The Authors wish to acknowledge the help given by several of their colleagues at the Midlands Research Station. In particular, thanks are due to Mr. P. Harris, for his experimental work on ignition, and to Mr. K. B. Walker, for his valued assistance in the development of the electronic equipment. Thanks are also due to various manufacturers of both industrial gas equipment and flame-protection units. Finally, the Authors wish to thank Dr. W. A. Simmonds for useful discussions during the preparation of this paper.

LITERATURE REFERENCES

[1] Francis, W. E. The Design of Air Blast Tunnel Burners. *Gas Council Res. Comm. GC*48.

[2] Francis, W. E., and Hoggarth, M. L. The Stability of Air Blast Tunnel Burners. *Gas Council Res. Comm. GC*68.

APPENDIX 1

THE CALCULATION OF UNLIT MIXTURE RATIO

The theoretical unignited air : gas ratio obtained with various types of burner can be calculated from a knowledge of pressure and flow conditions existing in the burner, as derived from the theory developed by Francis and Jackson in *Gas Council Research Communication* GC44. The pressure efficiencies of various types of burner are calculated in that paper and the theory of a parallel injector, parallel tunnel, burner is considered on page 25. This leads to equation (13), p. 27:—

$$\frac{A_5}{A_1}\frac{R^2}{(R+1)(R+\sigma)} = \frac{(S_{45}+2)}{2}\frac{(R+0{\cdot}7)}{(R+1)}\frac{T_5 A_2}{T_0 A_5} + \frac{(S_{23}+2)}{2}\frac{A_5}{A_2} - 1$$

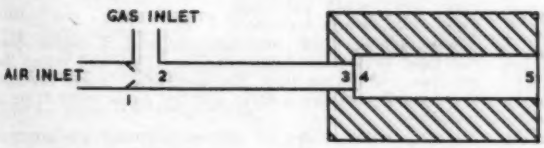
in which:—

A = cross-sectional area,
R = air : gas ratio,
S = frictional pressure loss in velocity heads,
T = absolute temperature,
σ = specific gravity of gas (air = 1),

and subscripts as shown in Figure 26:—

$_0$ = S.T.P. conditions,
$_1$ = air nozzle,
$_2$ = mixture tube, after entrainment and enlargement,
$_3$ = mixture nozzle (end of mixture tube),
$_4$ = combustion chamber after combustion zone,
$_5$ = exit nozzle.

PARALLEL INJECTOR, PARALLEL TUNNEL



PARALLEL INJECTOR, CONVERGING TUNNEL

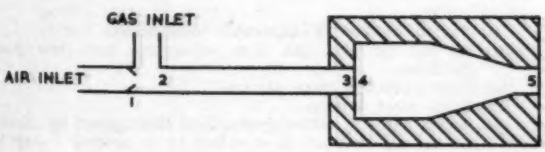


FIGURE 26.

In the unlit condition, $T_0 = T_5$. Also, the term $(R + 0{\cdot}7)$ is replaced by $(R + 1)$, since mixture is flowing through the tunnel. Therefore, the above equation becomes:—

$$\frac{A_5}{A_1}\frac{R}{(R+1)(R+\sigma)} = \frac{(S_{45}+2)}{2}\frac{A_2}{A_5} + \frac{(S_{23}+2)}{2}\frac{A_5}{A_2} - 1 \quad . \quad (1)$$

Now for a typical G6 gas $\sigma = 0{\cdot}5$, and for a practical burner the values of S_{23} and S_{45} may well be of the order of 0·3 velocity heads.

Hence, on substitution, equation (1) above becomes:—

$$\frac{A_5}{A_1}\frac{R^2}{(R+1)(R+0{\cdot}5)} = \frac{2{\cdot}3}{2}\frac{A_2}{A_5} + \frac{2{\cdot}3}{2}\frac{A_5}{A_2} - 1 \quad . \quad . \quad (2)$$

For an M.R.S. type A burner,

$$\frac{A_1}{A_5} = 0{\cdot}134, \frac{A_2}{A_5} = \frac{A_3}{A_5} = 0{\cdot}372$$

$\therefore$ Solving equation (2) for R gives an unlit mixture ratio of 1·015. Similarly for an M.R.S. type B burner,

$$\frac{A_1}{A_5} = 0{\cdot}0825, \frac{A_2}{A_5} = \frac{A_3}{A_5} = 0{\cdot}135$$

Substituting these values and solving equation (2) for R gives an unlit mixture ratio of 2·887.

The theory of a parallel injector, converging tunnel, burner is developed on page 30 of *Gas Council Research Communication GC*44, and this leads to:—
Equation (25) p. 31.

$$\frac{A_2}{A_1}\frac{2R^2}{(R+1)(R+\sigma)} = \frac{(R+0{\cdot}7)}{(R+1)}\frac{T_5}{T_0}\left[(1+S_5)\frac{A_2^2}{A_5^2} + \frac{A_2^2}{A_4^2}\right] - 2\frac{A_2}{A_4} + 2 + S_{23} \quad . \quad . \quad . \quad . \quad (3)$$

In the unlit condition, $T_5 = T_0$ and, as before, $(R + 0{\cdot}7)$ is replaced by $(R + 1)$. For a practical burner, $S_{23} = 0{\cdot}3$ and $S_5 = 0{\cdot}12$ velocity heads.

For an M.R.S. type C burner,

$$\frac{A_2}{A_1} = 3{\cdot}091, \frac{A_2}{A_4} = 0{\cdot}136 \text{ and } \frac{A_2}{A_5} = 0{\cdot}51$$

These various values can then be substituted in equation (3), which, when solved for R, gives an unlit mixture ratio of 1·172.

APPENDIX 2

SETTING-UP AND OPERATING INSTRUCTIONS FOR BURNER CONTROL SYSTEMS

The setting up and operating instructions given here refer to the burner control schemes given in the " Burner Control Systems " section of the paper. If the air fan used delivers 1 lb/sq. in. air pressure (27·7 in. w.g.), then a turndown of approximately 3·5 will be given with a low flow air pressure of 2 to 3 in. w.g. Such an air pressure enables the majority of tunnel burners to be ignited satisfactorily above their instability regions. However, should a greater

turndown be required, the low-flow air pressure should be determined from the instability data[2] for the burner concerned.

Scheme 1

Setting-up:

1. Ensure that the gas flow valve is shut, then switch on the fan.
2. Set the air flow valve to give 2 to 3 in. w.g. pressure at the air nozzle and mark the valve setting for future use (low-flow setting).
3. Fully open the main gas cock.
4. Depress the ignition push-button.
5. Slowly open the gas flow valve until the flame stabilizes. (A certain amount of ignition "noise" is inevitable.)
6. Release the ignition button. (If the flame goes out, turn off the gas immediately and repeat from 4 above.)
7. Trim the gas flow valve for optimum burner performance and mark its position (low-flow gas rate).
8. The air and gas flow valves may now be adjusted in small increments, opening the air valve first in each step, until the desired throughput is obtained.

Operating

(i) Ensure that the gas flow valve is shut, then switch on the fan.
(ii) Set air flow valve to low-flow setting.
(iii) Open the main gas cock.
(iv) Depress the ignition push button.
(v) Slowly open gas flow valve to low-flow setting.
(vi) Release the ignition button. (If the flame goes out, turn off the gas immediately and repeat from 4 above.)
(vii) The air and gas flow valves may now be adjusted to give the desired throughput as step 8 above.

Scheme 2

Setting-up:

1. Ensure that burner gas cock is shut, then switch on fan.
2. Set the air flow valve to give 2 to 3 in. w.g. pressure at the air nozzle and mark the valve setting for future use (low flow setting).
3. Fully open the main gas cock.
4. Adjust the gas restrictor to its mid-position.
5. Depress the ignition push-button.
6. Slowly open the burner gas cock to its fully open position.
7. Release the ignition button. (If the flame goes out, turn off the gas immediately and repeat from 5 above.)
8. Adjust the gas restrictor for reliable burner operation.
9. Fully open the air flow valve.
10. Trim the gas restrictor for optimum burner performance and lock it in position.
11. Move the air flow valve to the low-flow position.
12. If possible, adjust the atmospheric (zero) governor for optimum burner performance.
13. Throughput can now be adjusted by means of the air flow valve.

Operating:

(i) Ensure that the burner gas cock is shut, then switch on the fan.
(ii) Set the air flow valve to the low-flow setting.
(iii) Fully open the main gas cock.
(iv) Depress the ignition push-button.
(v) Slowly open the burner gas cock to its fully open position.
(vi) Release the ignition push-button. (If the flame goes out, turn off the burner gas cock immediately and repeat from (iv) above.)
(vii) Throughput may now be adjusted by means of the air flow valve.

Scheme 3

Setting-up:

As for Scheme 2, but the air flow valve must be operated from high to low by the low-flow switch, and the low-flow stop must be adjusted to give 2 to 3 in. w.g. pressure at the air nozzle.

Operating:

As for Scheme 2. Throughput is normally controlled between high and low flows by a thermostat, but can be switched to low-flow by means of the low-flow switch.

Scheme 4(a)—Semi-automatic

Setting-up:

1. Switch on the fan.
2. Set the air flow valve to give 2 to 3 in. w.g. pressure at the air nozzle and mark the valve setting for future use (low-flow setting).
3. Adjust the gas flow valve to be slightly open (i.e., about one-sixth).
4. Fully open the main gas cock.
5. Depress the start-button and trim the gas flow valve until the burner lights.
6. Release the start-button and adjust the gas flow valve for optimum burner performance and mark its position for future use (low-flow gas setting).
7. Throughput may now be adjusted by means of the air and gas flow valves as in scheme 1, step 8.

Operating:

(i) Switch on the fan.
(ii) Set the air flow valve to the low-flow position.
(iii) Set the gas flow valve to its low-flow setting.
(iv) Fully open the main gas cock.
(v) Depress the start-button for about 2 sec and release.
(vi) Adjust gas and air flow valves to give required throughput.

Scheme 4(b)—Fully-automatic

Setting-up:

1. Ensure that the gas flow valve is shut, then switch on the fan (if separately energized) and press the start-button.
2. Set the air flow valve to give 2 to 3 in. w.g. pressure at the air nozzle and mark the valve setting for future use (low-flow setting).
3. Allow unit to finish programme cycle.
4. Adjust gas flow valve to be slightly open (i.e., about one-sixth).
5. Fully open main gas cock.
6. Press start button for about 1 sec.
7. Allow unit to finish programming and if burner does not light press start-button again. This will purge the gas line. If burner does not light after fourth attempt, open gas flow valve a little and try again until flame is established.
8. Adjust gas flow valve for optimum burner performance and mark its position.
9. Throughput may now be adjusted by means of the air and gas flow valves as in scheme 1, step 8.

Operating:

(i) Switch on fan (if separately energized).
(ii) Set the air and gas flow valves to their low flow positions.
(iii) Fully open the main gas cock.
(iv) Press start button.
(v) When flame is established adjust throughput by means of the air and gas flow valves as in scheme 1 step 8.

Scheme 5(a)—Semi-automatic

Setting-up:

1. Switch on the fan.
2. Set the air flow valve to give 2 to 3 in. w.g. pressure at the air nozzle and mark the valve setting for future use (low-flow setting.)
3. Adjust gas restrictor to its mid-position.
4. Fully open main gas cock.
5. Depress the start-button and trim the gas restrictor until the burner lights.
6. Release the start-button and adjust the gas restrictor for reliable burner operation.
7. Fully open the air flow valve.
8. Trim the gas restrictor for optimum burner performance and lock in position.

9. Move the air flow valve to the low-flow position.
10. If possible, set the atmospheric (zero) governor for optimum burner performance.
11. Throughput can now be adjusted by means of the air flow valve.

Operating:

(i) Switch on the fan.
(ii) Set the air flow valve to the low-flow setting.
(iii) Fully open the main gas cock.
(iv) Press start-button for about 2 sec and release.
(v) Adjust the air flow valve to give the required throughput.

Scheme 5(b)—Fully-automatic

Setting-up:

1. Ensure that the main gas cock is shut, then switch on the fan (if separately energised) and press the start-button.
2. Set the air flow valve to give 2 to 3 in. w.g. pressure at the air nozzle and mark the valve setting (low-flow setting).
3. Allow the unit to finish programme cycle.
4. Adjust the gas restrictor to its mid-position.
5. Fully open the main gas cock.
6. Press start-button for about 1 sec.
7. Allow the unit to finish programming and if the burner does not light press start-button again. This will purge the gas line. If burner does not light after fourth attempt, open the gas restrictor a little and try again until a flame is established.
8. Adjust the gas restrictor for reliable burner operation.
9. Fully open the air flow valve.
10. Trim the gas restrictor for optimum burner performance and lock in position.
11. Move the air flow valve to the low-flow position.
12. If possible, adjust the atmospheric (zero) governor for optimum burner performance.
13. Throughput can now be adjusted by means of the air flow valve.

Operating:

(i) Switch on the fan (if separately energized).
(ii) Set the air flow valve to its low-flow position.
(iii) Fully open main gas cock.
(iv) Press start-button.
(v) When flame is established, adjust the air flow valve to give the required throughput.

Scheme 6(a)—Semi-automatic

Setting-up:

1. Ensure that the main gas cock is shut, then switch on the fan and adjust the low-flow air valve setting to give 2 to 3 in. w.g. at the air nozzle. Fully open the high-flow setting valve or stop.
2. Adjust gas restrictor to its mid-position.
3. Fully open the main gas cock.
4. Depress start-button and trim the gas restrictor until the burner lights. Release the start-button.
5. The burner will immediately go on to high fire and the gas restrictor must be trimmed and locked in this position.
6. Operate the thermostat or break its connexions, so that the burner goes to the low-fire rate.
7. If possible, set the zero governor for optimum burner performance.
8. The throughput may now be controlled between high and low by means of a thermostat or switch. The high-fire rate can now be adjusted if required.

Operating:

(i) Switch on fan.
(ii) Fully open main gas cock.
(iii) Depress the start-button for about 2 sec and release.
(iv) The thermostat or switch will now be able to control the throughput between high and low.

Scheme 6(b)—Fully-automatic

Setting-up:

1. Ensure that the main gas cock is shut, then switch on the fan (if separately energized) and press the start-button.
2. Ensure that the high-flow air valve or stop is fully open. and, at the appropriate part of the time cycle, adjust the low setting of the air flow valve to give 2 to 3 in. w.g. pressure at the air nozzle.
3. Allow the unit to finish programme cycle.
4. Adjust the gas restrictor to its mid-position.
5. Fully open the main gas cock.
6. Press the start-button for about 1 sec.
7. Allow the unit to finish programming and if the burner does not light press start-button again. This will purge the gas line. If the burner does not light after the fourth attempt, open the gas restrictor a little and try again until a flame is established.
8. Adjust the gas restrictor for reliable burner operation.
9. With the burner operating at high flow, trim the gas restrictor for optimum burner performance and lock in position.
10. Set the burner (by means of the thermostat) to operate at low flow. If possible, adjust the atmospheric (zero) governor for optimum burner performance.
11. The burner throughput can now be controlled between high and low flow by means of a thermostat or process switch. Additional switches can provide for on-off control and/or overriding shut-down.

Operating:

(i) Switch on the fan (if separately energized).
(ii) Fully open the main gas cock.
(iii) Press start button.
(iv) The burner will now light and run under automatic control.

PRESENTATION, DISCUSSION AND REPLY

Presentation

Mr. P. G. Atkinson presented this paper and summarized its contents.

Discussion

Mr. G. le B. Diamond, C.B.E. (Chairman, West Midlands Gas Board):—It is a great pleasure to open the discussion on the paper by Mr. Atkinson and Mr. Hancock dealing with the ignition and control of tunnel burners, because I have known the Authors for some years, and have watched their assiduous and painstaking work at the Solihull Research Station. This paper is itself testimony to the co-operative team work that is going on at Solihull. Although the research described was undertaken because of some difficulty—not great difficulty—that was found in the lighting of tunnel burners designed by Simmonds and Francis, it must not be overlooked that the reason for using more complex control systems is to simplify operation, that is to say, decrease the degree of operator responsibility.

The investigation into the best position for the high-voltage spark plug and the reasons for certain failures is presented as an interesting story. The facts leading up to the conclusions reached are progressive and simply illustrated by diagrams. It will not have escaped attention that in a world of sawn-off shot guns, we are now in the domain of the sawn-off sparking plug!

The Authors have brought to light several features of the mechanism of ignition of air blast burners not previously appreciated, if, indeed, known. These include the very large

variation between mixtures applied by the injector when the burner is lit compared with the same burner unlit, and the extremely quick response of air blast injectors to high-speed impulses in the mixture tube, which varies between 50 and 100 c/sec. That part of the work relating to automatic burner control systems also gives evidence of the close co-operation that exists with appliance manufacturers, and it has become a feature of much of the work of the Gas Council's Midlands Research Station.

The success achieved in finding a flame-sensing system tuned to work on flicker impulses in a certain frequency band, so that a.c. frequency is excluded, is a notable piece of work and will help to ensure the reliability of the automatic control equipment. Most of these controls can be and, of course, are being used for many other applications than those referred to. To name only two, there are the West Midlands Gas Board's air heat burner and the Keith Blackman suction burner.

The Authors have not mentioned maintenance and service. The advance of instrumentation is so great on the district and on the production side that, in my view, special measures will have to be taken to recruit and train personnel for the maintenance of electronic equipment of all kinds. The Authors have a particular flare for the kind of work involved in this research and are well versed in electronic circuitry, which is now playing an important part in all systems of advanced automatic control. I commend the paper, which is practical and of undoubted interest to all industrial engineers charged with the design and operation of automatic heating equipment.

Mr. P. J. Broomer (Wolverhampton):—The Authors are to be congratulated on a paper that will be of great value to burner manufacturers. Although desirable, it is not always possible to carry out such an intensive development programme as has been executed by the Gas Council's Midlands Research Station. The Authors' efforts are indeed commendable and much appreciated.

Over the past three years, I have had the opportunity of marrying the air blast tunnel burner to a number of comparatively low-temperature applications where large volumes of heated air have been required from a compact heat source, no space being available for conventional combustion chambers.

All but one application were average-sized tunnel burners with full flame-, power- and air-failure protection equipment. These burners were early types and had the means of ignition confined to a separate pilot burner in front of the tunnel with programming control to include a purge of the burner system, also the air circulation and exhaust of the drying oven of which the burner formed a part. Incidentally, the burner was fitted with a flame-failure (incorporating flame-combustion) detection system.

The installation of most interest is a burner fitted to a low-temperature heat exchanger feeding an air-replacement scheme to large batteries of paint-spraying cabinets. This burner was the first large unit to be fitted with a fully automatic control system on throughput—flame failure and integration with an industrial appliance, and it conforms almost exactly to the recommendations set out in the paper.

This burner has a maximum capacity of 7,000 cu. ft/hr, and the plant itself delivers 36,000 cu. ft/min. of air at 80°F.

Prior to this installation, we had not produced a burner with a capacity larger than 2,500 cu. ft./hr, and our first thoughts were to have two burners, each of 3,500 cu. ft/hr, together giving the required 7,000 cu. ft/hr throughput. However, the advantages of a single burner were such that it was decided to experiment with the larger unit.

The burner tunnel was calculated from the formulæ laid down by Francis in his first paper on this subject, but about this time he was convinced that shorter tunnels could be used to advantage, and we therefore chose a tunnel length equal to 2·5 diameters.

High/low control was decided upon, but, since for such a large throughput a zero gas governor was not at the time available, a conventional gas governor was used with the lead weights removed. This gave an effective gas pressure to the appliance of ¼ in. w.g.

The initial trials were encouraging, the burner operating comparatively quietly considering its size. Also, on high/low control, the change over was without hesitation and again reasonably quiet. When installed, the burner fires into an insulated chamber and it is almost impossible to tell whether it is on high or low rating.

Air is fed in the conventional way from a 30 in. w.g. blower to the injector where the gas is induced, mixing with the air in the mixing tube.

Both air and gas are controlled by weep relay valves of the high/low type operated thermostatically by solenoid cut-off valves in the weep line. These solenoid valves are wired to function simultaneously.

It was found necessary to give special attention to the balancing of the two valves, since, due to the wide variation in pressures—30 in. on the air side and only ¼ in. on the gas—the operating rates were at normal settings completely different.

During the first few months, ignition was effected by hot wire igniters with three mini-plugs mounted around the mixing tube a short distance from the exit end. These worked fairly well, but, in the light of further development work, it was decided to change to spark ignition, which was a decided improvement.

The control of the installation is arranged for single push-button operation, which not only ignites the burner, but puts the heat exchanger plant through a controlled purge cycle.

This particular installation has been running for two years and requires only periodic preventive maintenance, which leads us to believe that a rating of 7,000 cu. ft/hr is by no means a limit for this type of burner and control system. So far as we can see, size will only be limited by the availability of suitably large control valves.

In passing, I would mention that manufacturers of gas- and air-control valves could help considerably in giving some thought to the design of a high/low control valve that will give rapid operation coupled with minimum pressure drop—particularly pressure drop, which has been the main concern in achieving good turn-down rates from single-stage blowers. Economically, perhaps 7,000 cu. ft/hr is large enough, for plant requiring larger throughputs must be in itself somewhat costly. Therefore, the added expense of duplicated sequence-starting equipment and flame-failure devices will be readily absorbed.

The basic principles have been carefully set down in the paper; further, the Authors supply sufficient information for designers to achieve a successful working unit. This paper, if read together with the vast amount of published work by Francis, completes a most useful contribution to our knowledge of high-intensity gas-combustion systems.

Mr. D. J. Davies (London):—I should like to question the Authors regarding the vulnerability of the spark plug and spark plug high-tension lead to damage by heat—heat by radiation from the back wall of the burner block, or by heat "creep back" along the steel mixture-tube after the burner is turned out.

As the Authors are aware, the North Thames Gas Board has, during the past year, installed a number of new-pattern tunnel burners employing automatic spark ignition and flame control of this type. These burners have a maximum consumption of 4,500 cu. ft./hr (22½ therms). During the testing of the first unit, a minor explosion occurred in the combustion chamber of the appliance, causing some damage to the interior brickwork. Upon investigation, it was found that the insulation of the high-tension lead was destroyed and that the failure of the spark allowed an air/gas mixture to pass into the furnace, where it was ignited by incandescent brickwork. At that time, we were using a 5 sec period of spark and energizing the 3 in. gas solenoid valve, also for 5 sec instead of the usual 2 sec, because of the slow response of the spring-loaded zero governor. The steps taken to prevent a recurrence were: (i) the spark plug was moved a little further away from the back wall of the burner block; (ii) a polished aluminium shield was interposed between the plug body and the burner to reduce heat radiation on to it; (iii) the high-tension lead was passed through a 1 in. diameter tube, and air was blown through this tube, over the high-tension leads on to the spark plug; (iv) as this burner had three mixing tubes feeding into one burner tunnel, two plugs and transformers were used instead of the original one; (v) 5 sec spark and 2 sec energizing

of gas solenoid valve were employed; (vi) maintenance of an air supply through the burner, after gas is turned off.

Since then, I am happy to say, no further ignition troubles have been experienced.

These rather large and powerful gas burners are installed on plants operated almost entirely by women, who, with absolute confidence, start and stop the heating of the plant many times a day by the simple pressing of a button.

Recently, we were asked by a consumer to endeavour to increase the speed of melting on crucible furnaces. To achieve this meant increasing the gas consumption, and we suggested the use of the new-pattern air blast tunnel burner, and, rather hesitantly, mentioned that it would be necessary to employ spark plug ignition. To my surprise, the management of the firm expressed pleasure with such a system as they had always been frightened by the methods used by their foundry operators in lighting gas-fired crucible furnaces. This furnace has recently been installed and is under test, and many of the foundry employees have verbally expressed their pleasure with the ignition system.

Mr. G. W. Robertshaw (Manchester):—I add my congratulations to the Authors for this first work on the subject of ignition control of tunnel burners.

Undoubtedly, there is urgent need for this equipment. The time has arrived when many clients either demand, or can be very easily persuaded to accept, semi- or fully-automatic equipment, provided it is available in a suitable form and at a suitable price.

An essential aspect of this is the "packaging" of equipment so that it may be piped up with gas and electricity and then button-pressed.

The confidence that this work gives in the application of the controls described has a great psychological boost of being able to invite an audience to witness commissioning operations, instead of a surreptitious visit—after hours—to make sure that everything works correctly.

There is little to question in the paper, but comments on ignition work carried out in the North Western Gas Board's Area may be of interest.

We have concentrated on multi-hole burners, and, although out of context, I would mention that several hundred burners of one particular pattern are now in operation without problems of either noise or burner-head material troubles. Several of these burners have been fitted with h.t. spark ignition and can be ignited at any throughput.

I would enquire whether, in the case of Figure 4, it is necessary to duplicate governors. Manufacturers' equipment is rated for inlet pressures between 2 and 5 in. w.g. and is supposed to give satisfactory performance. Is the setting of the control so fine that dual governing is necessary?

It has been stated that other methods of detection are being investigated; do these include any type of pressure-differential mechanism? We have used this method in connexion with submerged-discharge burners in order to detect whether, in fact, flame is established.

I should like to comment on another method of lighting tunnel burners. With the burner that can be ignited outside the tunnel, it is quite a simple proposition to fit a flame-ignition burner that is air-cooled and which will provide a pilot flame in the main burner. I have had experience of several such installations, and a surprisingly small amount of air cooling is necessary to prevent high ambient temperatures from causing trouble.

Mr. S. D. Broughton (Fireye, Limited):—With regard to flame-failure safeguards, unfortunately we visited Solihull at too late a date for the tests. However, Mr. Atkinson has gone into flame-failure safeguards and I think he knows as much about them as we do.

The servicing of electronic controls will have to undergo revision by manufacturers, due to the fact that people who use electronic flame-failure safeguards cannot be expected to carry staff to maintain them. I feel that a school will have to be run by the manufacturers in order to train personnel on site. The company with which I am associated has, in fact, started a school, but users have not made use of it, though the company feels it ought to be considered in the near future, especially as interest is being aroused in this connexion. It is a happy thought for manufacturers of flame-failure safeguards, that somebody is putting forward safeguards as a necessity and not as a necessary evil. We can help a great deal by not emphasizing that flame-failure safeguards are in themselves flame-failure safeguards only, but controlled ignition units as well. A point has been made about pressure differential being a means of detecting flame. This has been gone into in the United States, and it has been found that the "drop-out" is not quick enough for pressure differential. It is my opinion that the only way of detecting flame is by seeing it.

The question of price has been mentioned. The point is: How much can we value safeguard? The price is a consideration when a number of burners are being employed on any appliance. However, sufficient profit must be made to enable the carrying out of further research. A safeguard does not necessarily imply paying for one unit, but paying for service, and also protecting the plant around a burner.

Mr. C. H. Hirst (Bristol):—It is quite apparent from all that has been said, that many future installations will include tunnel burners; complete or semi-automatic control is obvious. I am pleased because, the more controls there are, the more reliance may be placed in the plant. It is quite clear that every application of control will have to be carefully thought out, because of the nuisance value of shut-downs if they were frequent.

It is difficult to locate a fault on plant: it is difficult to know whether it is an electronic fault or a gas fault. The remarks made by Mr. G. le B. Diamond (Chairman of the West Midlands Gas Board) are very true. We must have some means of quick servicing. In the case of large firms, I do not think this requirement would arise, because they carry competent electrical staff, and such equipment is not new to them.

It is rather difficult to discuss controls precisely, because different applications call for different systems.

I cannot understand why one need bother with this type of valve for the operation of the air. The existing one, which is of the diaphragm type, has a large pressure drop. One firm is developing a snap-acting type; by fitting a dash-pot, it is possible to ensure a 5 to 10 sec opening. This might suit our purpose. In the meantime, I think that the single-burner application might well work with a motorized valve. A by-pass could be fitted to include a valve that would operate quickly.

It is said that, in connexion with flame-failure devices, there is no ultra-violet component in the furnace brickwork. Why is it that this has not been developed to a greater extent, because it seems that there might be a danger of simulation in flame of the radiation flicker type.

It seems a pity that a pilot light could not be incorporated with a flame-failure device. There are difficulties, but it might have been possible to use the present probe type of detector, which has not given much trouble.

I should like to ask the Authors whether they feel that the deadweight type of zero governor is preferable, or the spring-loaded type, and where these should be sited relative to the burners.

With multi-burner applications, of which I have had some experience, there has been some slight difficulty due to the close proximity of the burners. Feedback has occurred when trying to operate all three burners, or operating the third when two are already alight. Is there some means of rectifying this on an installation already in use, or is it a question of altering the whole of the electronic equipment?

Written Contribution

Mr. J. F. Inns (Barlow-Whitney, Limited, Bletchley) wrote:—Our work has shown us that, for satisfactory ignition of air blast burners, the igniter must be mounted as near to the mixture nozzle as possible, but, lacking the time to do exhaustive tests with varying igniter positions, we welcome the information quoted in the paper.

An example of the effect that incorrect positioning of the igniter can cause was shown recently when a customer was conducting trial tests on a sample burner. The burner was one

of our original prototypes, on which the igniter was positioned relatively far back. The l/d ratio was about 5, and the burner a "B" type consuming about 1,000 cu. ft/hr at 15 in. w.g. The control set up was as Figure 23 in the paper, with a fully automatic control unit.

In the ignition cycle, when the ignition period, which was 5 sec, was reached, the spark came on, the gas valve opened, the control unit registered flame "on" and thereupon extinguished the spark.

Unfortunately, due to the position of the igniter, a flame had been established in the mixture tube, but there had been insufficient time for a stable flame to be established in the tunnel, so, with the ending of sparking, the flame failed. This caused the flame relay to drop out, bringing on the spark again; the gas having been on continuously, this caused an explosion in the burner.

A slight modification arranged for the spark to continue for the whole of the ignition period, and this gave tremendous improvement. A new burner with the igniter positioned farther forward has eliminated all troubles, but it seems that the time between the establishment of the flame and the cessation of the spark is of importance.

All the control systems quoted in the paper, we have tried and found successful, although every automatic set-up seems to run into some slight teething troubles.

Using zero gas governors in various types of control set up, we have encountered several difficulties including that pointed out by the Authors, whereby the gas cut-off valve must be positioned between the zero governor and the burner in order to obtain satisfactory results.

We have also found that the ignition and turn-down characteristics of a burner are affected by the amount of restriction in the pipe from the zero governor to the burner, including that created by the solenoid valve. In a typical scheme as Figure 23, in the normal running position the output from the zero governor must be set to give a slightly negative pressure at the gas entry to the mixture tube. As there is a pressure drop through the gas pipe and valves, the output at the zero governor will in all probability have to be slightly positive. Upon turn-down, however, the pressure drop across the intermediate valves will decrease with decrease in gas flow, tending to give a richer mixture, which is undesirable for large turn-down.

It is also possible that the actual capacity of the pipework to the burner has an effect on ignition characteristic, but this is uncertain. We have had a control system that, after causing considerable trouble, suddenly worked perfectly when the length of pipe between the zero governor and solenoid valve was increased from a few inches to about 5 ft.

Apart from the systems quoted in the paper, we have used that mentioned briefly in section IV(2) with high/low valves in both air and gas lines. It is true that, as stated, the opening and closing times of the valves must be matched, and snap action valves are not suitable. However, the operating times of solenoid/relay valve combinations can be adjusted; once the correct settings have been achieved, the system works well.

There is one big advantage in this system, in that the mixture ratios on both high and low firing can be adjusted to precisely what is wanted. The development of a valve as suggested in the paper at the end of the sub-section on high/low control, would obviously simplify this type of control system and make it even more attractive.

A field of controls not covered by the paper is those applicable to multi-burner installations. Such experience as we have had has shown that, on systems having one zero governor feeding several burners to be ignited individually, serious interaction can occur, causing the ignition of one burner to extinguish another. We would respectfully suggest that further consideration be given to this problem.

Generally, there are difficulties in initially setting up an air blast tunnel burner control system, but, once this is done, the results justify the effort.

Spoken Reply

Mr. **R. A. Hancock,** in reply, said:—Mr. Diamond commented on the maintenance and servicing of control equipment. It would appear that the actual equipment used is partly electronic and partly standard industrial gas equipment. I think that we could expect the manufacturers of the electronic equipment perhaps to provide some servicing facilities for their components. Some of them are plug-in units that can be changed quickly on location of faults. With the gas equipment, I think that one could expect gas engineers to look into it.

One or two speakers have commented on the pressure drop across high/low valves when used in the air supply of air blast burners. We are interested in the development of a suitable valve to overcome this problem. We feel that there might be scope for pressure-operated butterfly valves.

Mr. Davies has commented on the vulnerability of the plug lead to heat. It is largely a problem of the location of the burner. He really answered his own question when referring to the possibility of putting cooling air around the plug leads and screening the plugs from back radiation. I think it is necessary to cool the mixture tube when the burner is turned off.

Mr. Robertshaw made some interesting comments on igniting multi-hole burners, and we should like more information on his experience.

He raised the point about using the appliance governor with a zero governor. Manufacturers of some zero governors say that their governors will have a zero pressure output over quite wide ranges, but I believe it has been common practice to use appliance governors.

A subject to which reference has also been made is the method of measuring differential pressure across the flame within a burner. We have looked into this and have used pressure switches actuated by back pressure to provide a flame-sensing device. Such a detector will respond very rapidly.

We have commented on the price of equipment in the paper. It depends on the application and the cost of the whole installation. (In this connexion, it might be interesting to consider the sale of cheap parachutes. Not many people would be interested.)

Written Reply

The **Authors,** in reply, wrote that they are pleased to find so much interest in the subject matter of the paper. The number of varied points made in the discussion shows how detailed this interest is. In addition to the oral reply made by Mr. Hancock they have the following comments to make:—

Mr. R. J. Broomer describes an automatically operated burner of 7,000 cu. ft/hr capacity that does not make use of a "zero" governor. The Authors have since had experience in the application of 6 in. zero governors, each passing 15,000 cu. ft/hr to a bank of three burners. Although rather large, these governors respond quite satisfactorily during the 2 sec allowed for proving ignition.

Mr. D. J. Davies mentions a minor explosion, caused partly by heat damage to the sparking-plug lead and partly by using a 5 sec trial for ignition period. It is, of course, important that the temperature of the sparking-plug and lead be kept to reasonable levels. In the case cited, the Authors understand that the soldered connexions melted, and it is possible that the burner design did not allow sufficient refractory insulation in the backplate. However, Mr. Davies has found an admirable solution where this problem arises. The explosion that occurred shows that one must be careful to ignite burners at both a low rate and for the shortest trial for ignition period that is practicable. The Authors have found that 2 sec is a suitable compromise, but, if calculation shows that a dangerous quantity of mixture can be present with this timing, then it would seem desirable either to prove the spark or to provide an independent pilot burner. The spark may be proven by using an ultra-violet flame detector, and it is hoped that before long a unit of this type will be available with programmed ignition control. It is also feasible to design a burner with dissimilar sizes of mixture tube and to use the smaller for ignition purposes. The latter comment bears directly upon that made by Mr. G. W. Robertshaw concerning alternative methods of igniting tunnel burners. Again, reference to the ultra-violet detector was made by Mr. C. H.

Hirst, and the Authors assure him that this American importation is being closely studied with a view to its application in burner control systems. The Authors' tests so far indicate that it does not operate from hot refractories, at least up to 1,200°C. Mr. Hirst mentions the use of probes. It is true that these can be used in certain cases, but high operating temperatures are difficult to deal with and the installation of probes requires expert knowledge. However, an integral pilot with a probe detector is feasible, and this system is worthy of consideration. Concerning the question of deadweight *versus* spring-loaded zero governors, it is considered that the two are complementary at present, the larger governors being weight-loaded whilst the smaller types often employ a spring. Those using long-rate tension springs have the advantage of no pivotal friction, but the Authors have found no definite advantage in either type for normal air blast burner applications. Another point that Mr. Hirst raises is that of flame detector cross-pick-up from adjacent burner ports. This is a difficulty arising from the particular burner design. It is suggested that consideration should be given to redesigning the burner so that it has only one combustion chamber, along the line suggested in the Gas Council's *Research Communication GC*68, by Francis and Hoggarth. In order to determine whether any advantage could be achieved by altering the electronic circuits, it would be necessary to analyse the frequency spectrum produced by the interfering signal. It is doubtful whether this would be greatly different from that due to the combustion itself, and Mr. Hirst might think that the former approach would be the better in this case.

Most of the ignition problems experienced by Mr. J. F. Inns can be explained as being caused by incorrect siting of the sparking-plug. Although it is possible to ignite burners with the sparking-plug further away from the backplate than we recommend, the troubles encountered by Mr. Inns must be expected. The effect of combustion vibrations coupled with resonant pipe lengths can make the solution for individual systems rather problematical. However, if the recommendations of the paper were followed, none of the effects that lead to unreliable ignition would arise, and there would be little interaction on multi-burner systems using the same zero governor.

The Authors agree with Mr. Inns that rich mixtures on turn-down are undesirable, but cannot agree that his method of usage of the burner and controls is correct. Normally, the gas pipe and valves between the zero governor and the injector should be sized so as to cause no undue restriction. If Mr. Inns finds it necessary to use a positive governor outlet pressure in order to obtain stoichiometric proportions at high flows, then obviously the mixture will go gas-rich on turn-down. Is Mr. Inns certain that his burners are manufactured to close enough tolerances? The Authors suggest that he uses a smaller air nozzle to increase the injection ratio, thereby allowing the use of a zero governor outlet pressure, plus the use of a restrictor to trim the air : gas ratio.

COST CONTROL IN RELATION TO THE GAS ENGINEER

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The Bronze Medal (1960) of The Institution of Gas Engineers was awarded for this paper, which was read at a meeting of the Eastern Junior Gas Association held in Cambridge on 20th April, 1960.

COMMUNICATION NO. 597

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I SUMMARY

The fundamental principles of cost accounting and cost control are summarized in Sections III and IV. In Section V, some of the practical applications of cost control in a gas works are discussed. The appendix on "Costing Terminology" covers the definitions of terms in more common use, and is inserted for general reference purposes as well as for use in connexion with this paper.

II INTRODUCTION

Without some knowledge of costing principles and the methods and purposes of cost control, the young gas engineer of today is at a distinct disadvantage, which is not in keeping with his future responsibilities.

In the Eastern Gas Board's Cambridge Division, the policy over many years has been to introduce modern methods of cost control; indeed, many original and unorthodox ideas in this field have been pioneered. As a result, the station engineer is fortunate in receiving a flow of varied costing information at regular intervals, which enables him to maintain close control of expenditure.

Cost control is part of our daily work and we must be able to use this tool effectively. This paper introduces some ideas on the subject in the hope that interest may be stimulated.

A sense of proportion must be maintained, for every decision cannot be governed by the economy angle as there are often other factors to be considered, such as working conditions, which may override the cost factor; even so, these other factors must be considered in relation to their influence on cost.

The introduction of a cost control system does not in itself result in improved efficiency. It is a system of measurement and the results obtained must be promptly and correctly interpreted and effective action taken when necessary if the desired improvement in efficiency is to be achieved.

The main purpose of costing is "external" in support of sales to provide a basis for fixing selling prices; the secondary purpose is "internal" in assisting to promote efficiency and economy in production.[1] It is with the secondary purpose that this paper is chiefly concerned. It is dealing with cost control that the engineering and the accountancy functions come in closest contact. Each functionary should learn as much about the other's duties as is necessary to enable a smooth exchange of information and ideas, and the Author has drawn much of his material from accountancy literature, chiefly from outside the gas industry. The object of the paper is to provide a basis for discussion on a subject with which we are, perhaps, not always as familiar as we should be.

III THE PRINCIPLES AND PURPOSES OF COST ACCOUNTING[2]

The Principles of a Cost Control System

Before tackling the practical aspects of cost control, it is perhaps advisable to remind ourselves of the basic principles of a cost control system and to summarize its purposes.

It is important for us to understand the potentialities of the scheme in order that we can utilize it to fullest advantage in our daily work.

(i) *Costing Defined*

Costing is the classifying, recording, and appropriate allocation of expenditure for the determination of the costs of products or services, and for the presentation of suitably arranged data for purposes of control and guidance of the management. It includes the ascertainment of the cost of every order, job, contract, process, service or unit, as may be appropriate. It deals with the costs of production, selling, and distribution.

(ii) *Estimates and Costs*

Estimates are not costs, from which they differ in several ways. Usually, estimates are based on present or prospective market prices of materials and labour, and, while previous costs ascertained may be used as a guide in fixing prices, it is sometimes expedient to prepare estimates on a competitive basis, making quotations even below cost, to avoid greater loss where there is costly plant and fixed overhead expenses are heavy. Members on the sales and service side may have some comments to make on this latter point.

Costs accounts, however, record the actual costs of materials, wages and expenses. It has been said very aptly that "an estimate is an opinion, price is a policy, and cost is a fact". The ascertained costs provide a measure for estimates, a guide to policy, and a control over current production.

(iii) *Statistics and Costs*

The preparation of statistical returns and cost summaries must not be regarded as cost accounting, but rather as a method of presenting to the management results ascertained by the aid of the costing system. Statistical reports serve to interpret the cost accounts and other information collected in the course of their compilation. Cost statistics not prepared in conjunction with cost accounts that interlock with financial accounts is information that fails for the want of proof.

(iv) *Desirable Conditions for a Costing System*

(1) The system should be adapted to suit the organization, otherwise it will prove unsatisfactory owing to resentment of officials and probable lack of co-operation.

(2) Study the technical aspects and make an effort to receive sympathetic assistance and support of staff and workers generally.

(3) Minimum details in which records are compiled should be arranged. Over-elaboration of analysis must be avoided as this tends to undue and costly clerical work. Nevertheless, the whole work of production and services should be covered.

(4) Records to be made by foreman and workers should involve as little clerical work as possible. It is advantageous to provide written or printed instructions as to the origin, use, and disposition of each form.

(5) Every original entry should be signed to ensure reliable statistics.

(6) Promptitude, frequency, and regularity in presentation of costs and statistics must be arranged for.

(v) *Summary of Purposes of Costs Accounts and Statistics*

(1) The expenditure recorded and summarized in the financial accounts is analysed and classified with reference to the cost of products and operations.

(2) To arrive at the cost of production of every unit, job, operation, process, department or service, and develop cost standards.

(3) To indicate to the management any inefficiencies and the extreme of various forms of waste, whether of materials, time, expense, or in use of machinery, equipment and tools. Analysis of the causes of unsatisfactory facts may indicate remedial action.

(4) To provide data for periodical (revenue) accounts at such intervals as may be desired, not only for the whole business, but also by departments or individual products.

(5) To reveal sources of economies in production, having regard to methods, types of equipment, design, output, and layout, daily, weekly, monthly or quarterly information may be necessary to insure prompt constructive action. Potential economies may be revealed.

(6) To provide actual figures of cost for comparison with estimates, and to serve as a guide for future estimates or quotations.

(7) Where standard costs are prepared, they show what the cost of production should be, with which the actual eventually recorded costs may be compared.

(8) To present comparative cost data for different periods and various volumes of production output, and to provide guidance in development. This is valuable in connection with budgetary control.

(9) To indicate where articles, components or services can be bought more advantageously than made.

(10) To record the relative production results of each unit of plant and machinery in use as a basis for examining its efficiency. A comparison with the performance of other types of machines or plant may suggest the necessity for replacement.

(11) To provide a perpetual inventory of stores and other materials, so that (*a*) interim balance sheets can be prepared without stocktaking; and (*b*) checks on stores and adjustments are made at frequent intervals.

(12) To explain in detail the sources of profit or loss revealed in total in the revenue account.

The engineer must have sufficient knowledge of the costing and administrative procedure of every section of the business in which he is engaged.

IV THE PURPOSE OF COST CONTROL

(i) *Control of Costs*

One of the more important tasks of any engineer is the control of costs. The control is actually accomplished in two ways. One is the psychological impact that the review of performance has upon the way departmental heads perform, and the other is the review of costs that enables management to correct deficiencies that would otherwise be unnoticed.

(ii) *Psychological Impact*

If the various levels of management know that their performance is being reviewed, they are more likely to be on the lookout for inefficiencies and to take steps to rectify these situations. The psychological impact is impossible of measurement, but it is possible that this is the most important contribution of a cost accounting—cost control system.

(iii) *Review of Costs*

Standard and budgeted costs are the backbone of any cost control system. They set the "par" or goal that management attempts to attain. The standard can be attained only by a high level of efficiency. If the actual costs are in excess of the standard costs, then management has not reached this high level of efficiency, and the unfavourable variance from standard costs must be explained.[3]

In the U.S.A., a technique of management that is widespread is the use of budgets and forecasts of activity against which the performance of the company can be checked. One company employs accountants in the operating departments who provide what amounts to a "running commentary" by watching certain key figures.[4]

(iv) *Flexible Budgets*

The flexible budget procedure for controlling costs compares the actual cost to the budgeted cost at the same level of operations. Comparing costs at the same level of activity is extremely important, since the reporting of the incurred cost has control significance only when compared with what the cost should have been at the same level of activity.

The flexible budget procedure implies a knowledge of how costs will be affected by changes in the level of operations. The nature of the cost (how it will react to changes in activity) can be determined in either of two ways:

(1) By a study of how the cost should theoretically react to changes in activity (for example, wages of material handlers on piecework may be expected to be variable, since the more activity, the more material to be handled).

(2) By a study of how the cost (or costs) has reacted to changes in activity. (This problem is most simply solved by using a graphical solution.)

The first of the two procedures is the preferred method. It eliminates the danger of using past experience as a guide in setting standards. When past experience is used, past inefficiencies are built into today's standards. The standards should reflect a high level of efficiency, not merely what has happened in the past.

However, past experience may be useful in showing the attainable level of efficiency. It may also uncover factors that influence costs, but which have previously been ignored: for example, some costs may increase as the activity increases, but may then show a reluctance to decrease when the level of operations slackens (for example, overtime may have to be worked for a specific task, but when the task is completed the overtime remains). Another method of uncovering inefficiencies is to compare the cost experience of different plants of similar characteristics. This often will uncover areas where important inefficiencies have been occurring. An American company, in comparing the heat expense of its different plants, found that a Chicago plant had higher costs than its other plants. This was at first blamed on the Lake Michigan winds, but engineers disproved this explanation. Size of plant also did not account for the high heat bill. The answer was found in an open loading platform. The firm was literally attempting to heat all of Chicago.[2]

(v) *Standard Cost Accounting (Budgetary Control)*

One definition of standard costing is as follows:—"Standard costing is the use of constant values for material cost accounting records and the comparison of such constants with actual production costs and expenditure, in detail, in groups or in total".

The principle is to establish standard basic values in advance of production for raw materials, labour rates, production performances, aggregate outputs; to prepare basic expense schedules, or budgets, for manufacturing expenses and overheads, and to incorporate these records in the accounting system in order to show the variations between the basic (standard, budget or anticipated) costs and the actual costs and expenditure incurred.

Standard costing has been in operation in various crude forms since the time of Francis Bacon (16th to 17th century), although only in recent years has it been developed and publicised as a special form of costing.

Cost estimating has always preceded production, and the cost estimate is the standard against which the manufacturer has always compared his actual production costs.[1]

With the development of industry in the past 30 years, it is no longer necessary to wait apprehensively for the annual surprise of the cost of gas into holder or the profit and loss account, hoping for the best and possibly fearing the worst.

It is possible to ascertain, almost week by week, and certainly month by month, how a district is faring, and manufacture, supply and sales service can be undertaken with the confidence of sound knowledge.

The use of permanent standard costs can be advocated when production is:

(1) reasonably stable in form and in total output,

(2) subject only to minor changes in production methods,

(3) highly detailed, making the recalculation of all standard costs annually, or biannually, a major operation involving excessive clerical work.

After a number of years in use, permanent standards may become remote from actual costs owing to:

(1) changes in production methods and layout.

(2) extension of plant,

(3) major increases in materials costs and labour rates of pay. Recalculation may become essential. The principle of retaining the same standard costing basis should be held as long as is practicable.

(vi) *Annual Standard Costs*

The recalculation of standard costs each year is considered, in the Author's opinion, the ideal method. Each year, all standard costs are revised in the light of the current level of materials, prices, wages, rates and overhead recovery rates.[1]

The main advantage of an annual recalculation is that comparisons are not obscured by minor changes in detail brought forward from previous years, and each year's costs accounts start from scratch.

The Author favours the 13 four-weeks period for accounts and statistics prepared during the year, which must give a clearer and more direct indication of current progress, uninfluenced by the cost variations of previous years as in the four-, four- to five-week system.

Briefly, the advantages of the four-weekly basis are:—

(1) Seasonal trends may be seen more easily as they are not obscured by the interpolation of figures representing uneven periods of time.

(2) Comparisons between one period and another can be made accurately.

(3) An irrelevant variation is eliminated.

(4) The allocation of fixed charges on a time basis is constant.

V THE PRACTICAL APPLICATION OF COST CONTROL

(i) *Establishing Responsibility*

Two of the primary precepts of any method of cost control are that definite responsibility for the cost must be established, and that an officer must be held responsible only for those costs that he can control.

Costs should be recorded and accumulated by areas of responsibility. These areas of responsibility may be entitled departments, cost centres, overhead centres, *etc.*, but, whatever the title, the goal is to accumulate costs so that the efficiency of the person responsible for the costs may be judged.

The precept that an officer cannot be held responsible for costs that he cannot control means that reports must be prepared with non-controllable costs carefully labelled as such, or left off the report entirely. In too many cases, the attention of executives is focused on the size of costs over which no control is being exercised by the person whose efficiency is supposedly being measured.

(ii) *Reports*

It is necessary to balance the cost of obtaining prompt reports with the usefulness of getting information while it is still significant. The timing of reports is extremely important. A labour report in the hands of the works engineer 12 h after the event has occurred is much more useful than the same labour report delivered 30 d later. Monthly cost reports may be better than none at all, but they are a poor substitute for daily or weekly reports that are placed in the hands of management fast enough so that the causes of the inefficiency can be corrected before they waste resources for a month. Explanations are also earlier and more significant if the person explaining inefficiencies is explaining something that has happened on the preceding day.

(iii) *Overheads*

The allocation of manufacturing overhead costs to operating departments, and the absorption of the overhead costs to find unit costs of product, often result in confusion when attention is shifted to the control of costs. The allocation of overhead does not assist in the control of costs. To control costs, it is necessary to focus attention at that point where the costs are incurred. Thus, to control the cost of the works function, it is necessary to investigate the costs of the works departments that were incurred in the works departments and not to consider the size of the cost allocations from the Area Headquarters, Divisional Chief Office, *etc.* The allocation of these costs is relevant, but not for the control of costs.

(iv) *Cost Control and People*

Costs are not controlled by the issuance of reports, but by their use by members of management in making decisions that will result in costs being less than they would be if the data had not been accumulated and circulated. The importance of people in this process should not be overlooked. Only by the action of people in authority will costs be controlled.[2]

The technical staff at all levels must actively develop their knowledge of cost control and how accounting reports can help to accomplish this end. The job of the accounting department does not end with the preparation of a report. The person receiving the report should be helped to understand it, and also to understand how it can be used to help him do his job more efficiently.

(v) *Control of Distribution Sales and Service and Administrative Costs*

The focus of attention of this text is on the control of manufacturing costs This is not meant to imply that the control of administrative costs and the costs of distribution and sales and service is not important The same types of procedures and reports used to control manufacturing costs should be used to control non-manufacturing costs

Several problems in the control of non-manufacturing costs should be noted. Administrative costs and sales and service costs are often less controllable than manufacturing costs: for instance, how can one measure with certainty whether the advertising expenditures are excessive, or that the salesmen are travelling too much—or not enough? Another problem may arise because it may not be possible to identify the administrative cost or selling cost with one product. If a salesman is selling gas and coke, how much of his costs should be allocated to each product?

(vi) *Costs Accounts Codes*

The use of costs accounts codes in the works is facilitated by posting and displaying suitable references on notice boards, walls, doors, and vehicles, as only the more responsible workers, clerks and officials require full copies of the costs codes plan for the allocation of expenses. The effective working of the whole costs accounts organization is dependent on the full co-operation and consistent accuracy of the personnel making the primary records, as, in general, costs accounts coding is carried out by the person originating a record, e.g.,

(1) the operator on working out his time record,
(2) the technical assistant or foreman on writing out the material requisition,
(3) the storekeeper on requisitioning new materials from the purchasing department and on receiving new materials from outside and other departments.
(4) the purchasing department on preparing invoices for entry to the accounts and cost accounts and subsequent payment,
(5) persons presenting cash vouchers to the cashier for payment.

With accurate and reliable coding of original documents, the work of the costs department in this connexion is confined to scrutiny verification and analysis of the records thus properly provided. The methods of analysing primary records are innumerable, and various combinations of specialized machinery, coloured forms and patented systems may be used, according to the volume of work.

It is in the preparation of the primary records that industrial accountancy comes into its closest contact with works administration, production planning and progress. The primary records of the costs accounts are generally the primary records required for daily works management and production control. The two functions are complementary.

The method of costing used does not in any way affect the need for a close integration of the cost accounts with the production control records. Process, job, standard, contract, *etc.*, costing methods all require the same basic information of production and progress, and production programme and cost budgets can be used in parallel to trace variations and their causes, between anticipated expenditure and the actual results.[1]

(vii) *Marginal Items*

There are many marginal items of fixed and variable expenses. There are also many marginal items of accounts charges and of departmental charges. Where particular expenses may be chargeable to one or more accounts, care must be taken to ensure that reasonably similar charges are consistently booked to the same account.[1] To draw a clear-cut division between heating, lighting and power

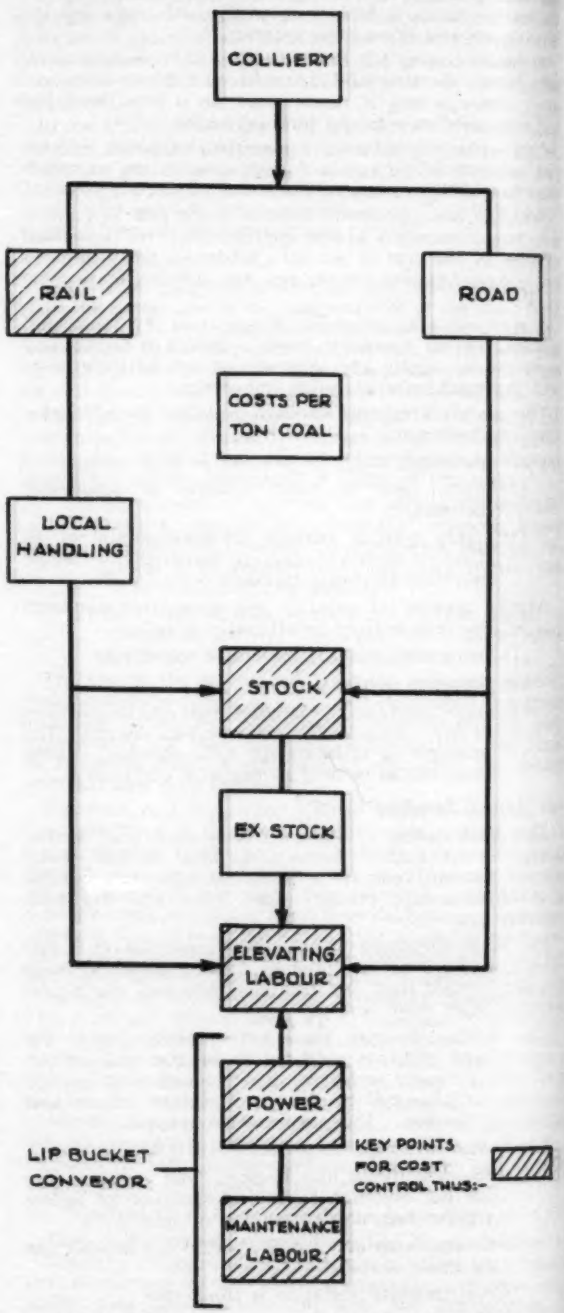

CHART 1.—*Coal Flow Diagram.*

expenses is frequently difficult; it is also relatively immaterial provided that the allocation of expenses is consistent and gives a regular period-by-period comparison of expenditure: for example, repairs to a steam distribution main passing through one department to serve another may be charged to:—

(1) the department being supplied by steam, unless the main supplies more than one department,
(2) the department in which the main lies and where the repair is being performed,
(3) the boiler plant itself, as the delivery-point of steam to the point of consumption is part of the steam service.

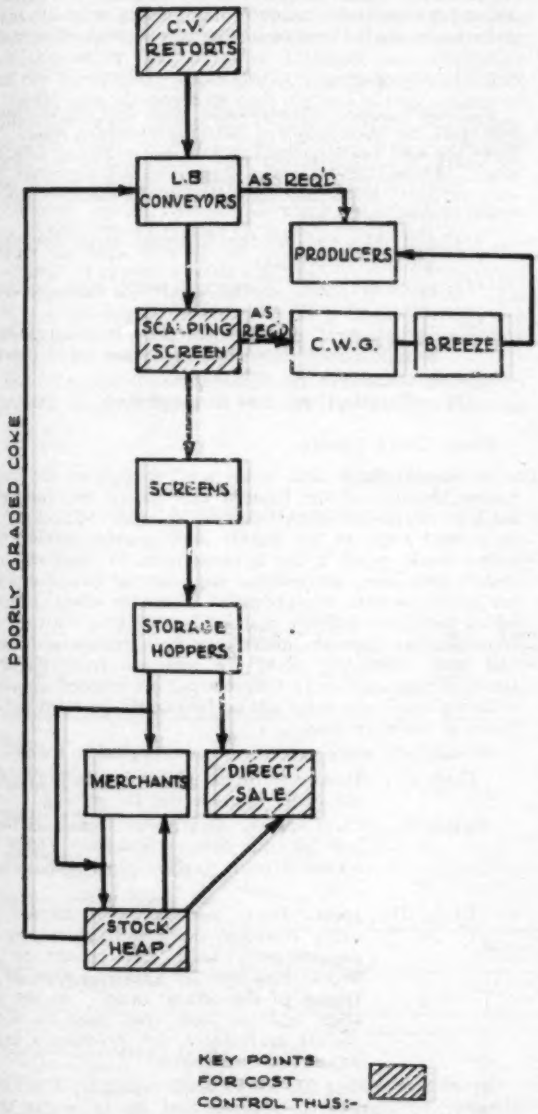

CHART 2.—*Coke Flow Diagram.*

The third is generally regarded as being the best basis, the rule being that the boiler plant is chargeable with repair costs on its own side of the main departmental supply valves. Similarly, repairs to electric power distribution cables are chargeable to the electric power department if on the supply side of the main departmental meters and switches; if the repair lies between the departmental control and the consumption-point, then the repair is chargeable to the consuming department and not to the electric power department.

(viii) *Key Points of Control*

There are certain key points of control for production efficiency and costing.

(1) Raw-materials handling (Charts 1, 2 and 3)
(2) Production. (Monthly Cost Statement.)
(3) Repairs and Maintenance.
(4) Materials in stores.
(5) Project expenditure.

(ix) *Production*

It is not within the scope of this paper to go into details of technical control and economic control, but it is important to emphasize most strongly the fact that technical control and cost control are integral, being complementary and not competitive.

The technical statistics kept daily by the technical staff in relation to the respective plants are really the focus for immediate action where required, and, if the standards set have been achieved, it should follow that the monthly cost of gas into holder will be up to standard so far as the manufacture and purification processes are concerned.

The monthly cost statement of cost of gas into holder is an example of historical costing, as it is received some three weeks after the end of the month concerned. The efficiency of technical and cost control is highlighted, and the report is an invaluable guide to the progress of production costs throughout the year. This report should be read in conjunction with the monthly statistical report on production.

The argument has been advanced that as there must be x stokers in the retort house, each of whom must be paid y pounds, then the money expended in the retort house must be xy pounds, over which the technical assistant in charge of the house has no control. This is a misinterpretation, for cost control is not concerned solely with expenditure; it involves also output under defined conditions and over a given period.

$$\frac{\text{Expense}}{\text{Output}} = \text{Cost per unit of output (e.g., therms made, tons of coal handled)}^5$$

It is obvious that at all possible times plant should be used to its full capacity.

Technical assistants should be encouraged to calculate in whatever manner they choose, what they consider should be the cost of running their particular plant. They may then be presented with this equation.

$$\text{Actual Cost} = \frac{\text{Standard Cost}}{\text{Efficiency (per cent)}}$$

Some very illuminating discussions will no doubt result.

Among the key points that concern cost control in the retort house are, for example, type of coal, throughput, temperature of retorts, percentage steaming, moisture in coke, fuel to producers, *etc.*

(x) *Instrumentation*

In the technical press a few months ago,[6] there was a photograph of a control panel, a section of which illu-

strated the instruments primarily provided to present essential information required for budgetary control.

Here one is faced with the problem of whether the cost of an instrument is worth the degree of cost control it affords; the correct balance must be found. Too many instruments can be as confusing as too few. The most obvious example of a cost control instrument is the recording calorimeter. There are carbon monoxide recorders, outlet retort house governor recorders, pressure gauges, *etc.*, all closely linked with cost control. On the other hand, steam meters are very expensive, their installation not always easy to justify.

The main point to bear in mind is that instruments are there for a purpose and not merely for adornment. Instruments do not correct faults; they merely record or register them. Where readings are logged, and where charts are interpreted, it is most important that prompt and effective action be taken on any variance from the standard, and that standard should be known by all personnel concerned.

(xi) *Maintenance and Repairs*

In his paper,[7] to the Eastern Junior Gas Association, Mr. W. M. Johnston dealt with the cost control of this item at some length, so the author will content himself with the following remarks.

One of the greatest hindrances to efficient planning and progressing is too large a volume of work in progress. It should be the aim of management to maintain the smallest possible volume of partly finished jobs about the works.

The first task of planned maintenance is to ensure that the correct materials are available at the right time in the required quantities. This task is not always easy to achieve and applies particularly to plant overhauls, planned for limited dismantling and ending up with major repairs due to unforeseen wear to normally inaccessible parts. This invariably entails delay in obtaining replacements from the manufacturers of the unscheduled sections and is wasteful in that labour has to be taken off the job as well as the plant being idle. Careful record keeping should obviate repetition of this to any single plant.

Possibly, the greatest losses, and often the least realized losses are due to the building up of an excessive volume of work in progress. The losses are difficult to trace and equally difficult to arrest when a large amount of work is awaiting further operations. The losses may be due to:

(1) excessive movement of work, stocking, stacking, shifting, *etc.*,
(2) delays due to general confusion,
(3) work performed correctly, but by wrong methods due to indefinite instructions,
(4) production in excess of instructions left unfinished,
(5) rectifiable work not corrected,
(6) time occupied with work not immediately required while more urgent work is overlooked.

(xii) *Control of Stocks*

The problem of determining and controlling the level of stocks is one of the most important problems that we face. There is danger that we may ignore the problem of stock control and incur various unnecessary costs that accompany excessive stocks. Unfortunately, many of the costs arising from excessive stocks appear to be "normal"; thus, the problem of controlling stock costs is best solved by attacking the core of the problem, i.e., the size of stock required.

Costs of Carrying Stocks

What are the costs of carrying goods in stock? It should be recognized that these costs will be losses arising from inefficiency if the stock on hand is excessive. Among the costs connected with the carrying of stock are:

Storage Space Costs.
Handling Costs.
Interest on Capital Invested as Stock.
Risks of Spoilage and obsolescence.
Paper Work (including the costs of counting the excessive stock).

It has been estimated that the annual costs of carrying stock are approximately 10 per cent of the cost of the stock. The validity of this rule of thumb will, of course, depend on the characteristics of the items in stock, but it does dramatize the cost of inefficiency in controlling stock.

Costs of Insufficient Stocks

Inefficient stocks management is a two-edged sword. Not only are there costs of carrying excessive stocks, but there are also costs connected with not carrying sufficient stock. These costs or losses sometimes are forgotten, but they are every bit as important as carrying excessive stocks. Some of these costs are:

(1) lost sales because the customer could not obtain the desired product,
(2) transport costs connected with rush purchase orders of parts and material,
(3) disruption of maintenance programmes, resulting in labour inefficiences and overtime costs to catch up on production schedules,
(4) trunk telephone calls to suppliers.

Works Stock Checks

At Peterborough and, I am told, thoughout the Cambridge Division of the Eastern Gas Board, the following method of works stocks control is used. Checking of stock-card trays at the weekly staff meeting enables the entire works stock to be covered item by item approximately once every six months. An ordering level is decided for all items with the exception of major plant sections, which cards are suitably marked for bringing forward for consideration when the items have been drawn from stock and used. Obsolete items are removed from the tray. Items coming into more frequent use are stepped up at the ordering level, and items not so frequently required are cut down at ordering level.

Broadly, the stock-card items are classified as follows:—

Class I. *Standard Stock Items.* Automatically, the order is made out for signing.

Class II. *Plant Spares.* Draft orders only are made out by the Stores Ordering Clerk for approval prior to the typing of the official order.

Class III. *Special Items Not Carried in Stock.* The order is raised on a draft form by the departmental head and passed to the Works Engineer for approval prior to the typing of the official order. As the cost code and the item cost must be shown on the draft form, this provides a useful adjunct to cost control.

By thus reviewing the works stock regularly, it has been possible to control the capital tied up in works stock (amount £17,000), as well as ensuring as far as possible that the right material is in stock in the correct quantity.

Normal Demands

The stores are closed for specific periods during the day. This has a twofold advantage:

(1) Personnel have developed the habit of drawing material from the stores in sufficient quantity to do specific jobs instead of making piecemeal withdrawals.

(2) A continuous and planned day to day stocktaking allowing a checking of records with physical stock without any interruption to normal demands on the stores. This system is known as perpetual inventory.

(xiii) *Revenue Budgets (Manufacture)*

Chart 3 illustrates the basic form used for budgetary control in the Cambridge Division of the Eastern Gas Board. The target figures in column 11 are allocated to each District by the Divisional Engineer in consultation with the Divisional Accountant. It is up to each District in the Division to devise its own method of cost control to attain these target figures and thus keep within the budget. The cross totals show the total of each type of expense (subjective classification), and the vertical totals show the total of each kind of activity (objective classification).

Although not all Districts have a local cost accountant or a statistician, the receipt of statistics and costs accounts reports are dealt with by the Divisional Accountant's department. A report a week after the event is not to pregnant of action as a fair estimate within 24 or 48 h. This does not presuppose that the reports from Division are useless; this is far from the case as these are the yardstick by which the works cost control system is judged.

The objective classification is not sufficiently detailed to segregate all departmental sections, though by planning ahead and by suitably breaking down of the target figures it is possible to allocate responsibility to the sectional officers in the form of the budget they have to control, which, checked frequently, shows whether or not their function is costing what it should.

Wages

Under the existing system, a summary of works wages, suitably detailed over the relevant cost codes and split into departments and sections, is the subject of a monthly report from the accountants. This report is normally received a few days after the end of the month and repays careful study. However, variance of wages for any given week in the month, and the cause, is not highlighted, and an opportunity for cost control may thus be lost.

To counteract this possibility, each departmental head having a given establishment is responsible for the overtime worked in his department. During his weekly timesheet check each Monday, the overtime hours are extracted and entered against the appropriate employee's name, together with a concise report of the reason. The report is discussed at the staff meeting next day, together with any requests for overtime in the current week. Overtime approved is entered in the appropriate column, and any hours worked in excess of this is entered in the "emergency" column as obviously it is not always possible to forecast precisely how long a job may take or whether emergency jobs may crop up necessitating a call-out after normal hours.

Using these reports, it is possible to calculate quickly the weekly wages of the department, together with the percentage overtime. A check against the standard or budgeted figure reveals any variance, and, where this is the case, an immediate discussion takes place whilst the matter

EASTERN GAS BOARD—CAMBRIDGE DIVISION

REVENUE BUDGETS (MANUFACTURE). COSTS FOR THE WEEKS ENDED 19

DISTRICT

Element of Cost	Coal Handling etc.	Coke Handling for C.W.G.	Process Charges	Repairs and Maintenance	Works General Charges	By-Products Charges *	Power Charges	Total Charges for Month	Total Charges Months to date	Actual Year 1959-60	Budget Year 1960-61	Balance of 1960-61 Budget	Months to date: Proportion of Budget	Months to date: Over-spent Under-spent
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	£	£	£	£	£	£	£	£	£	£	£	£	£	£
Wages														
Salaries (including Foremen) ...														
Materials ex Stores...														
Invoices (excluding Gas Making Materials)														
Transport (excluding Coke Delivery)														
Storekeeping														
Electricity Sold to Eastern Electricity Board (Camb. only) ...														
Month's Totals														
Months Totals to Date												Last Month		
Revenue Project Expenditure included in Above												Improvement or *Deterioration* in current month		

* Excludes : Coke Selling Expenses (Codes 50/82, 50/91—92)

Cambridge.

CHART 3.

STAT. 9

EASTERN GAS BOARD (CAMBRIDGE DIVISION)

.....DISTRICT

COST STATEMENT SUMMARY

Statement of Gas Manufactured — ending 6 a.m.

	1 THIS MONTH		2 THIS YEAR TO DATE		3 12 MONTHS ENDING WITH CURRENT MONTH		4 ACTUAL YEAR ENDING 31st MARCH LAST	
	Total £	Per Therm Pence	Total £	Per Therm Pence	Total £	Per Therm Pence	Total £	Per Therm Pence
COAL								
Coal Handling								
COKE for C.W.G.								
Coke Handling								
GAS OIL								
HEAVY OIL								
TOTAL FUELS								
RESIDUALS								
Coke and Breeze								
Tar								
Ammonia								
Benzole								
TOTAL								
NET RAW MATERIALS								
PROCESS								
Wages								
Miscellaneous								
PURIFICATION								
Wages								
Materials								
POWER								
REPAIRS & MAINTENANCE					*	*		
RETORT RESETTING								
GENERAL CHARGES								
CAPITAL CHARGES								
Depreciation								
Interest								
TOTAL COST								
Total Therms Produced								
C.V. B.t.u.								

* Actual.

REPAIRS AND MAINTENANCE				
	FOR MONTH £	TOTAL FOR YEAR TO DATE £	PENCE PER THERM TO DATE	PENCE PER THERM TARGET
WORKS				
MAINS & SERVICES				
GASHOLDERS				
PUMPING PLANT				
POWER PLANT				

% Inc. or Dec. on last Full Year (Col. 3 compared with Col. 4)	
COAL	
OIL	
TOTAL FUELS	
NET RAW MATERIALS	
PROCESS WAGES	
TOTAL COST	

CHART 4.

is fresh in the minds of all concerned; if necessary, corrective action may be taken without expensive delay.

Salaries

The number of personnel on the staff side remains reasonably constant and the salary expenditure is reasonably constant week to week, affording a straightforward comparison with the budget figure. The activity of the staff is reflected in the efficiency of their departments, for which they are, of course, responsible.

Materials on Standard Stocks

The extraction of the information from the stores requisition "slips" and the costing of materials each day is obviously a prolonged business and it has not been found possible to obtain a quick check on the costs of materials drawn from stores. However, with the standard stock system and method of stocks control used, the ordering of these stock items is closely related to the usage. Therefore, to obtain a quick check, the necessary expenditure information is extracted from the standard stock orders typed daily. These are totalled daily to the nearest pound, and a running total kept for each costing period.

Materials Not on Standard Stock

The method of presenting official orders has previously been discussed. In addition, when the official orders are typed, the cost to the nearest pound is extracted by the typist and entered in the appropriate cost code column of the budget cost form. A running total is kept daily for each four- or five-week costing period, thus providing a quick check on invoice revenue expenditure against the target figure for that month which is boldly printed on the top of the sheet.

(xiv) *Projects*

Capital and revenue projects cost the gas industry large sums of money each year. The size of these projects may vary from a complete new gas works to, for example, the modifications to an existing water-softening plant.

A capital project may be classed as expenditure on new plant, whilst a revenue project is money spent on the modification of existing plant.

Preliminary reports from which much of the final project material is drafted are often provided by the technical staff. This gives excellent training in the following ways:

(1) The gathering of technical information.
(2) The investigation in the costs of the proposed scheme.
(3) The collation of the material gathered.
(4) The writing of a concise and coherent report.

Ideas should be advanced and freely discussed, for "good ideas are the prerogative of no one person's brain. Everyone should be encouraged to make suggestions for the more efficient running of his undertaking."[8] This applies, of course, to routine work generally at all levels and not to projects in particular.

Money for development is applied for, to The Gas Council, by Area Gas Boards some years in advance. Each Division is granted a sum each year to cover the developments envisaged.

Strictly speaking, no allowance is made for emergency developments. The capital development budget is actually a very tight one, especially so for 1960-61. Unexpected capital expenditure can only be catered for by deferring some other item(s) allowed for when the programme is prepared, unless it can be accommodated because certain other agreed capital expenditure is running behind schedule.

This has to be looked at from an Area point of view: under-expenditure in one Division can be made available if necessary to balance an over-expenditure in another, but, strictly speaking, there is no sum allowed in the capital development programme for emergency developments, and the Ministry of Power's global allocation to the Board for each year has to be adhered to closely.

Projects are raised for final approval at divisional or Area level, depending on the amount of money required, and, when this is granted, work on site may commence.

The estimates of the cost of the job have been very carefully made and money for that scheme is duly allocated.

If the project is overspent, then money must be drawn from reserve, possibly holding up other developments.

If the project is underspent and all money set aside has not been used, this results in money lying idle which could have had a planned use on some other project.

The procedure of the Board's Divisional Accountants' departments for notifying overspendings on project work is interesting. Divisional Engineers are advised each month (*a*) when a project is first overspent, and (*b*) if previously reported, the amount of the current overspending. In the future, they are hoping to inform him when there is an overspending in respect of Board's labour and materials irrespective of whether there is a total overspending.

In either case, this may indicate inaccurate estimating, or inadequate cost control may materially affect the allocation of money to other projects. There are often unforeseen circumstances that swallow up the contingencies allowed, such as a rise in labour rates. In such cases, an immediate report must be made to the appropriate headquarters in order that the necessary financial adjustments can be made.

Frequent inspection of the site work and weekly inspection of the costs to date, the amount of money still available together with the weekly progress report, with prompt action when required, should enable the responsible officer to control the cost of the project.

Where a project is split into several sections, for costs purposes, the departmental officers must be informed of the appropriate code numbers, to avoid confusion resulting from miscoding.

In many instances, projects take several months to complete, and, even when contractors have left the site, there are apt to be several items to be attended to by district labour. It is important to inform all departments concerned when the actual project work has finished, so that the correct cost accounts code and not the project costs code may be applied to any further work on the plant concerned.

The costs should be finalized as soon as practicable, and the responsible senior officer should be informed, in writing, together with the reasons for any variations from the allocated cost. Failure to do this promptly may lead to "witch-hunts" many months later, with frantic searches through masses of paper to find why project number XYZ was overspent £300.

Acknowledgments

The Author wishes to thank the Chairman of the Eastern Gas Board (Mr. J. H. Dyde, O.B.E.) and the Cambridge Divisional General Manager (Mr. J. Hunter-Rioch, M.B.E.) for their kind permission to publish this paper.

His thanks are due also to Mr. E. H. Winch (Cambridge Divisional Engineer) and Mr. H. H. Tongue (Cambridge Divisional Accountant) for their helpful suggestions, and, particularly, Mr. F. A. Rhead, (Cambridge Divisional

Production Engineer) and Mr. L. Woolley (Peterborough District Accountant), and to members of the Peterborough staff who assisted in the preparation of this paper.

Bibliography

[1] Cost Accounting in Industrial Management, by H. Fisher and D. L. Thompson.
[2] Cost Accounting and Costing Methods, by H. J. Wheldon.
[3] Managerial Accounting, by Harold Bierman, Jnr.
[4] Anglo-American Council on Productivity (Productivity Report on Gas, 1953.)
[5] The Appreciation of Factors Affecting Cost in the Gas Industry, by M. S. Risk. *Trans. Inst. Gas Eng.*, 1953-54, **103**, 746.
[6] The Murton Coking Plant—2. (*Coke and Gas*, Sept., 1959.)
[7] Towards Preventive Maintenance, by W. M. Johnston. Paper to Eastern Junior Gas Association, 17th April, 1958.
[8] Col. Sir Harold Smith, K.B.E. (First Joint Conference between Gas Council, Area Boards and Trades Unions. Oct., 1953.)
[9] Costing Terminology. (Institute of Cost and Works Accountants.)

General Reading

Scientific Management, by F. W. Taylor.

APPENDIX

COSTING TERMINOLOGY

DEFINITIONS[9]

Costing.	The technique and process of ascertaining costs.

Types of Costing

Historical Costing.	The ascertainment of costs after they have been incurred.
Standard Costing.	The ascertainment and use of standard costs and the measurement and analysis of variances.
Marginal Costing.	The ascertainment, by differentiating between paid costs and variable costs, of marginal costs, and the effect on profit of changes in volume or type of output.
Uniform Costing.	The use by several undertakings of the same costing principles and/or practices.

Costs

Cost.	(*a*) The amount of expenditure incurred on a given thing. (*b*) To ascertain the cost of a given thing.
Fixed Cost.	A cost that tends to be unaffected by variations in volume of output.
Variable Cost.	A cost that tends to vary directly with variations in volume of output.
Controllable Cost.	A cost that is influenced by the action of a given member of the undertaking.
Uncontrollable Cost.	A cost that is not influenced by the action of a given member of an undertaking.
Material Cost.	The cost of commodities supplied to an undertaking.
Wages.	The cost of remunerating by (wages, salaries, commission, *etc.*) the employees of an undertaking.
Expense.	The cost of services provided to an undertaking, and the national cost of the use of owned assets.
Depreciation.	The diminution of the intrinsic value of an asset due to use and for the lapse of time.
Overhead.	The aggregate of indirect material cost, indirect wages and indirect expense.
Indirect. Wages/Expense/Material cost.	Wages/Expense/Material cost that cannot be allocated, but which can be apportioned to, or absorbed by, cost centres or cost units.
Production Cost.	The cost of the process that begins with supplying materials, labour, and services and ends with primary packing of the product.
Selling Cost.	The cost incurred in promoting sales and retaining custom.
Distribution Cost.	The cost of the process that begins with making "the gas available for the district and ends at the consumer's meter."
Administrative Cost.	The cost of formulating the policy, directing the organization and controlling the operations of an undertaking, which is not related directly to a research, development, production, distribution, or selling activity or function.

Prices

Price.	(*a*) A money rate used to calculate a cost. (*b*) To record a money rate in order to calculate a cost.
First in, First-out Price.	(F.I.F.O.) The price paid for the material first taken into the stock from which the material to be priced could have been drawn.
Last in, First-out Price.	(L.I.F.O.) The price paid for the material last taken into the stock from which the material to be priced could have been drawn.

Standard Costing

Standard Costing.	The ascertainment and use of standard costs and the measurement and analysis of variance.

Standards

Basic Standard.	A standard that is established for use unaltered over a long period of time.
Current Standard.	A standard that is established for use over a short period of time, and is related to current conditions.
Expected Standard.	The standard that it is anticipated can be attained during a future specified budget period.

Normal Standard.	The average standard that it is anticipated can be attained over a future period of time, preferably long enough to cover one trade cycle.
Ideal Standard.	The standard that can be attained under the most favourable conditions possible.
Standard Hour.	A hypothetical hour that measures the amount of work that can be performed in 1 hour.

RATIOS

Efficiency Ratio.	The standard hours equivalent to the work produced, expressed as a percentage of the actual hours spent in producing that work.

VARIANCE ANALYSIS

Variance Analysis.	The resolution into component parts, and the explanation of variances.

COST VARIANCES

Cost Variance.	The difference between a budgeted cost or a standard cost and comparable actual cost incurred during a period.
Controllable Cost Variance.	A cost variance that can be identified as the primary responsibility of a specified person.

BUDGETARY CONTROL

Budgetary Control.	The establishment of budgets relating the responsibilities of executives to the requirements of a policy, and the continuous comparison of actual with budgeted results, either to secure by individual action the objective of that policy or to provide a basis for its revision.

BUDGETS

Budget.	A financial and/or quantitative statement, prepared prior to a defined period of time, of the policy to be pursued during that period for the purpose of attaining a given objective. Types of budget include : Fixed, flexible, basic, current, functional, summary and master.

MISCELLANEOUS

Principal Budget Factor.	The factor the extent of whose influence must first be assessed in order to ensure that the functional budgets are reasonably capable of fulfilment.
Budget Cost Allowance.	The cost (exclusive of the direct materials cost) that a budget centre is expected to incur during a given period of time, in relation to the level of activity attained by the budget centre.

RATES OF DEPRECIATION

Single Rate of Depreciation.	A depreciation rate that is calculated by reference to the estimated life of a single asset.
Composite Rate of Depreciation.	A depreciation rate that is calculated by dividing by the aggregate of the costs of a number of assets of various individual lives the aggregate of the depreciation charges for one period of each of the assets depreciated, each aggregated depreciation charge being calculated by reference to the life of the appropriate asset.
Group Rate of Depreciation.	A composite rate of depreciation that is calculated by reference to a group of assets.
Accelerated Rate of Depreciation.	The depreciation rate that consists of a normal depreciation rate, augmented to provide for additional depreciation sustained by the asset depreciated because of abnormally increased usage of that asset.

(*Conclusion of Reference* 9).

METHOD OF CALCULATING DEPRECIATION

There are nine accepted methods of calculating depreciation, and the method used by the Eastern Gas Board is known as the " Straight line Method ". This is over a period of 21 years for pre-vesting assets, whilst post-vesting assets are depreciated according to the procedure laid down by The Gas Council, which shows the life of various classes of plant and machinery.

AMORTIZATION

Amortization.	The gradual extinction of a liability, usually by means of a sinking fund ; also, the process of spreading over a fixed period the depreciation in value of wasting assets, such as leases and royalties.

OVERHEADS

Overheads.	All items of " overhead " are dissected and collected under headings and are subsequently distributed in some suitable manner that ensures their fair allocation to departments or centres for recovery upon each individual cost unit by means of expense rates.

ALLOCATED TO FUNCTION

Employees' Welfare.
Depreciation.
Interest Payable.
Divisional Expenses.

NOT ALLOCATED

Rates.
Interest charges on working capital.
Area Board and Gas Council expenses.

MINOR OVERHEAD EXPENSES, e.g., garage overheads, are first collected under an overhead code, which in turn is reallocated to individual vehicle costs and are then charged against the various codes based on the function of the vehicle.

In this Issue . . .

T. Nicklin

E. Brunner

P. G. Atkinson

R. A. Hancock

B. Santo

T. Nicklin was born in Durham in 1916. He received his early scientific training at Loughborough College, from which he obtained the B.Sc.(Hons. Chem.) (London) in 1936. In 1950, he was awarded the Degree of M.Sc. (London) in Chemical Engineering, for a thesis on effluent treatment, and in 1958 was awarded the Degree of Ph.D. for his thesis on heat transfer under granular flow conditions. He became an Associate Member of the Institution of Chemical Engineers in 1943, and is a Member of The Institution of Gas Engineers. Before joining the gas industry, Dr. Nicklin worked first in an oil refinery, then as technical assistant at Stewart's and Lloyd's coke oven plant at Corby, and later as chemical engineer to W. C. Holmes and Company, Limited. In 1945, he joined the United Kingdom Gas Corporation as production engineer. When the Corporation was vested in the North Western Gas Board, he was appointed to a similar position at Board headquarters. He was appointed Chief Scientist to the Board in 1957. He has been the author of several papers to the Manchester Junior Gas Association, and joint author of two papers to the Manchester District section. In 1951, he was awarded the Silver Medal of The Institution of Gas Engineers for a paper of which he was joint author.

E. Brunner was born in Basle, Switzerland, in 1903. After education in the classics, he studied chemistry at the University of Basle, where he was awarded the degree of Ph.D. for his thesis on "Oxidations with Gaseous Fluorine". He did post-graduate work in 1929 at Birmingham, under the late Sir. W. N. Haworth, on the degradation of cellulose. He returned to Switzerland and in 1930 joined C.I.B.A. as a research chemist on dyestuffs. He was then transferred to The Clayton Aniline Company, Limited, one of C.I.B.A.'s affiliated companies, in 1932, and was appointed Research Manager in 1948. He has been a member of the management since 1956.

P. G. Atkinson was educated at the Bromley County Grammar School, where he became House Captain of Bisphams ; he took a keen interest in the Air Training Corps and became Senior Flight Sergeant. In 1946, he was granted an Exhibition award by the Kent County Council and subsequently became a student of the University of London, at Woolwich Polytechnic, where he was one of a small group of students who lived in the limited hostel accommodation. His main subject was Special Chemistry, with Mathematics as a subsidiary. Interest in electronics as a hobby, and the spare-time building of a television receiver led to the design of high-quality audio amplifiers ; as a result, some of the then modern electronic techniques applied to physical chemistry attracted his attention. In 1949, Mr. Atkinson graduated with honours in Science. He joined the Gas Research Board at Beckenham in September, 1949, and was employed on several projects before being called up for National Service in December of the same year, when he became an instructor in the Education Branch of the Royal Air Force Technical Training Command. In 1952, he was demobilized and resumed employment with the Gas Research Board. When the Board was dissolved, he transferred, in 1953, to the Midlands Research Station of The Gas Council, and joined the Utilization Group. Here he studied the measurement of gas stream temperatures, which led to the presentation of two papers (GC33 and GC57) to the 1956 and 1958 Autumn Research Meetings of The Institution of Gas Engineers. In 1956, he became leader of the then newly formed Instrument Section at the Gas Council's Midlands Research Station, in whose new laboratory research and development of controls in connexion with application of the air blast tunnel burners of W. E. Francis has taken place and led to the presentation of GC69.

R. A. Hancock was educated at Yardley Grammar School, Birmingham (1947 to 1954), and left at 18 to join the staff of The Gas Council Midlands Research Station as a research assistant. As a part-time student, he studied applied physics for one year at the College of Advanced Technology, Birmingham. A four-year sandwich course then followed, which ended with a final period of industrial training, in September, 1959, and the award of the Diploma in Technology and the Associateship of the College (A.C.T.(Birm.)). During his first year as a research assistant and during industrial periods of the sandwich course, which were all at The Gas Council's Midlands Research Station, Mr. Hancock carried out research, under a graduate scientist, on a number of topics relating to the industrial utilization of town gas. These included an investigation of factors influencing the emissivity of town gas flames, a study of the construction and performance of re-circulating driers (this involved also the development of an instrument for measuring high humidities), the development of a cellular thermally insulating refractory material suitable for use up to 1,900°C, which led to Patent No. 37405/57, and the study and analysis of the noise produced by air blast burners, with the object of reducing it. Since his graduation he has worked with Mr. P. G. Atkinson, B.Sc., on the ignition and control of air blast burners, which led to the publication of GC69.

B. Santo was educated at St. Austell County Grammar School and at Kingswood School, Bath. He entered the gas industry in 1938 and was an articled pupil at the Truro Gas Company. He joined H.M. Forces in 1943. A Captain in the Royal Engineers, he served in Italy and the Far East. On leaving the Army, in 1947, he attended the Institution of Gas Engineers Intensive Course at Cambridge. In 1948, he was appointed Technical Assistant at Cambridge Works, Senior Technical Assistant in 1949, and in 1950 became Assistant Works Engineer. In 1952, he was appointed Works Engineer at the Peterborough Works of the Eastern Gas Board, and in 1960 was appointed to take charge of gas production at Peterborough. At present, he is a member of Council of the Eastern Junior Gas Association.

News from the Gas Industry Overseas

8th International Gas Conference

The 8th conference of the International Gas Union was held, in Stockholm, on 28th to 30th June, 1961, under the Presidency of Mr. Bengt M. Nilsson. The conference was held under the patronage of H.R.H. The Duke of Halland, who was unfortunately prevented, by indisposition, from attending, but from whom a telegram of good wishes was received.

Mr. Gosta Agrenius, of the Stockholm City Council, welcomed the delegates to Sweden at the opening session at which the speeches were interposed with fanfares of trumpets and with folk music played on four violins by Swedish musicians in national costume.

Mr. K. Neuerburg, Chairman of the Gas Committee of O.E.E.C., Paris, referred to the close collaboration that existed between the various international organizations, professional and governmental, that are concerned with gas problems. The International Gas Union is the oldest and in his view the most important of these. He expressed the appreciation of his committee for the considerable assistance it received from the Union.

Mr. Nilsson, in his Presidential Address, reviewed the development of the International Gas Union since its formation, largely on the initiation of the British and French Gas Organizations, in 1931. There were 20 member countries until the current conference at which Finland was unanimously elected, making 21. He reviewed the development of the gas industry, with particular reference to the enormous increase in gas utilization where natural gas is available. He dealt also with the collaboration that the International Gas Union has with international governmental organizations such as E.C.E. in Geneva and O.E.E.C. in Paris. He referred to the reorganization of the Standing Committees of the Union for the undertaking of technical investigations. The existing standing committees, most of which were initially set up for the purpose of studying specific problems, are to be disbanded and in their stead seven main functional committees are to be initiated. These committees will appoint sub-committees and panels to study any specific matters coming within the purview of their functions.

Various member countries have been invited to provide the chairmen and secretariat for these functional committees as follows :—

Committee on Natural Gases ..	United States of America.
Committee on Production of Manufactured Gases	Great Britain.
Committee on Transmission of Gases	Germany.
Committee on Distribution of Gases	Germany.
Committee on Utilization of Gases	France.
Committee on Statistics	Belgium.
Committee on Documentation and Sundry Questions	The Netherlands.

Mr. J. van Dam van Isselt, of The Netherlands, was unanimously elected President of the International Gas Union for the period 1961 to 1964. In expressing his appreciation of the honour conferred upon him, Mr. van Dam van Isselt referred to his hope that the next International Gas Conference would be held in Amsterdam.

The British party, organized by The Institution of Gas Engineers, was the largest party from any country, comprising 122 members and 79 ladies. The British party included the President of the Institution, the Chairman and Deputy Chairman of The Gas Council, the Chairmen of several of the Area Gas Boards, together with other representatives of the Area Boards, plant and appliance manufacturers and the Gas Press. Mr. J. A. Beckett, C.M.G., Under Secretary, Ministry of Power, also attended the conference.

Other European parties included Germany (100 members, 35 ladies), France (88 members, 45 ladies), Sweden (83 members, 23 ladies), with smaller parties from Austria, Belgium, Czechoslovakia, Denmark, Finland, Italy, The Netherlands, Poland, Rumania, Spain, Switzerland and the U.S.S.R. There were also 47 delegates and 33 ladies from the U.S.A., and representatives from Canada and Australia.

Forty-eight reports and papers were presented and discussed, including reports from five of the standing committees, and four international reports, the information in which was collected on an international basis and collated by panels of experts appointed by various gas associations. Two were from Great Britain, one from France, and one from Germany. Individual papers were presented by delegates from member countries of the Union as follows : Australia (4), Austria (4), Belgium (2), Czechoslovakia (2), France (3), Germany (3), Great Britain (3), Italy (2), The Netherlands (4), Rumania (2), Sweden (1), Switzerland (1), U.S.A. (3), U.S.S.R. (4).

A complete list of papers is given below, and copies are available, on loan, from the Library of the Institution.

A number of interesting social events were included in the programme, and of particular interest was a reception in the magnificent Town Hall, Stockholm, which was used also for the official banquet. There was also an excursion to Drottningholm, a royal palace from the 17th Century, where, in the original theatre, a delightful performance of Pergolesi's " Il Maestro di Musica " was given by artistes from the Royal Swedish Opera.

Ladies' excursions were arranged for every day of the conference, and, following the conference, there were a number of touristic excursions organized by the Reso Travel Bureau.

At the concluding session, tributes to the work of the International Gas Union were given by Sir Henry Jones, M.B.E., who was the official representative of the World Power Conference, and by Dr. Koranyi, who represented E.C.E.

REPORTS AND PAPERS PRESENTED AND DISCUSSED AT THE 8TH INTERNATIONAL GAS CONFERENCE, STOCKHOLM, JUNE, 1961

(*a*) **Reports of Standing Committees:**

IGU/ 1-61 International Statistics of the Gas Industry. (Association Royale des Gaziers Belges.)

IGU/ 2-61 Report by the International Committee for the Harmonization of Essential Clauses in the Specifications for Stamping of Gas Appliances.

IGU/ 3-61 Report of the Committee for the Study of New Gas Distribution Techniques.

IGU/ 4-61 Report of the Committee for the Study of the Interchangeability of Gases.

IGU/ 5-61 Report of the Committee for the Study of Safety Conditions in Domestic, Commercial and Industrial Gas Appliances.

(*b*) **International Reports:**

IGU/ 6-61 Results of an International Enquiry on the Cathodic Protection of Gas Pipelines. (Arbeitsgemeinschaft des Deutschen Gasfachs.)

IGU/ 7-61 Processing Methods for Particular Gases According to their Nature and Utilization Characteristics. (Association Technique de l'Industrie du Gaz en France.)

IGU/ 8-61 Second Investigation on Unconventional Flues. (The Institution of Gas Engineers.)

IGU/ 9-61 Further Survey of the Development of the Use of Petroleum Products in Town Gas Manufacture. (The Institution of Gas Engineers.)

(*c*) **Individual Papers:**

IGU/10-61 Carbonization of Low-quality Coal and Subsequent Use of Coke in a Carburetted Water Gas Plant, by D. O. Vick. (Australia.)

IGU/11-61 Network Analysis of Gas Distribution Systems, by J. C. Challis. (Australia.)

IGU/12-61 Aspects of the Operation and Development of the Lurgi High-pressure Gasification Plant at Morwell, Australia, by B. B. Bennett. (Australia.)

IGU/13-61 Carburetted Water Gas Operations in the Australian Gas Light Company, by Maurice V. Gilbert. (Australia.)

IGU/14-61 Cause and Effect of Raising the Calorific Value of Vienna Town Gas from 4,250 to 4,600 kcal/nm³, by W. Jorde. (Austria.)

IGU/15-61 Supervision and Regulation of a Natural-gas Transmission System, with particular reference to Automatic Mixing Plants Using Multiple Ultra-short Wave Frequencies, by A. Lazek and F. Huber. (Austria.)

IGU/16-61 Measures and Installations Necessary for the Distribution of "Mixed Methane"—Regulating and Safety Devices for Automatic Equipment, by K. Sigmund. (Austria.)

IGU/17-61 Conversion of Existing Coal-gasification Plants to the Catalytic Reforming of Natural Gas, by F. Huber. (Austria.)

IGU/18-61 A Coal Viscosimeter, by J. de Brouwer. (Belgium.)

IGU/19-61 Present Trends of Coal Gas Production in Belgian Coking Plants, by A. Verhaegen. (Belgium.)

IGU/20-61 Liquefied Gas Storage in Caverns, by Geo. R. Benz. (U.S.A.)

IGU/21-61 Thermionic Converters for the Direct Generation of Electricity from Gas, by George N. Hatsopoulos and John A. Welsh. (U.S.A.)

IGU/22-61 Gas-fired Thermocatalytic (R) Reactors—A Flameless Incandescent Source of Thermal Energy, by Gerhart Weiss. (U.S.A.)

IGU/23-61 Steam in Gas Production, Association Technique de l'Industrie du Gaz en France.

IGU/24-61 Gas Sales Promotion Techniques, by R. Dury and J. Charlier. (France.)

IGU/25-61 Natural Gas in France, and Its Treatment, by L. Barbouteau and R. Guillo. (France.)

IGU/26-61 Calculation of the Economics of Long-distance Gas Transmission Systems, by H. Descazeaux and J. Ramond. (France.)

IGU/27-61 Heat Services by Gas in Houses and Flats in Great Britain, by L. W. Andrew and D. R. Wills. (Great Britain.)

IGU/28-61 Liquid Natural Gases for Town Gas Supply—A Review, by J. Burns and L. J. Clark. (Great Britain.)

IGU/29-61 Some Developments in Industrial Gas Utilization, by R. F. Hayman and W. A. Simmonds. (Great Britain.)

IGU/30-61 Thermal Behaviour of Coals at Various Stages of Oxidation, by G. Malquori and R. Sersale. (Italy.)

IGU/31-61 Repairing and Reinforcing the Concrete Tank of an 80,000 m³ Gasholder, by G. Vitali. (Italy.)

IGU/32-61 The General Adoption of the Units of the "Système International d'Unités" in the Gas Industry, by D. Tinbergen. (Netherlands.)

IGU/33-61 Gas leakage Detection by Dogs, by J. van Dam van Isselt and J. G. de Voogd. (Netherlands.)

IGU/34-61 The Significance of Gas Quality and Pressure to Distribution and Utilization Technique, by A. van der Linden. (Netherlands.)

IGU/35-61 Economical Diameters in Pipeline Systems at Given Supply and Outlet Pressures, by H. A. A. de Melverda. (Netherlands.)

IGU/36-61 The Mixture Reaction in Flames for Industrial Heating Appliances, by R. Günther. (Germany.)

IGU/37-61 Investigation into the Advantages and Disadvantages of Using Coal, Oil or Natural Gas as Raw Material for Town Gas Production in Germany, by H. Pichler. (Germany.)

IGU/38-61 Gas Heating in the Construction of Houses, by G. Düwel, W. Stehn and F. Awe. (Germany.)

IGU/39-61 The Utilization of the Jet Compressor for the Transmission of Natural Gases in the Roumanian People's Republic, by A. Pascaru and P. Svoronos. (Rumania.)

IGU/40-61 A New Process for Removing Gasoline from Natural Gases Dissolved and Associated with Petroleum, by I. A. Niculescu and N. Petcu. (Rumania.)

IGU/41-61 A New Centrifugal Gaswasher—New Possibilities for the Treatment of Coke Oven Gas, by S. W. Dahlbeck. (Sweden.)

IGU/42-61 The Production of Town Gas with Reduced Carbon Monoxide Content, by F. Jordi. (Switzerland.)

IGU/43-61 The Exploitation of Coking Plant Gas for Distribution in Czechoslovakia, by S. Odehnal. (Czechoslovakia.)

IGU/44-61 The Progress of Gas Distribution in the U.S.S.R., by F. A. Trebin and A. I. Sorokin. (U.S.S.R.)

IGU/45-61 Technique of Gas Line and Compressor Station Construction in the U.S.S.R., by Vassily S. Turkin and Alexey N. Yuryshev. (U.S.S.R.)

IGU/46-61 The Calculation of Pipelines and the Prerequisites for Choosing Optimum Gas Transmission Conditions, by A. V. Alexandrov, B. V. Barabash and I. E. Khodanovich. (U.S.S.R.)

IGU/47-61 The Problem of Underground Gas Storage in the U.S.S.R., by N. S. Erofeev. (U.S.S.R.)

IGU/48-61 The Economical Effectualness of the Gas Usage, by Vaclav Hrádek. (Czechoslovakia.)

IGU/49-61 Transactions of the 8th International Gas Conference, Stockholm, 1961.

Association Technique de l'Industrie du Gaz en France

The 78th Conference of the Association Technique de l'Industrie du Gaz en France was held at Saint-Malo from 14th to 17th June, 1961, under the Presidency of Monsieur Y. Quéret. A large number of delegates from foreign gas associations were welcomed at the opening session including representatives of the gas associations in Austria, Belgium, Germany, Great Britain, Italy The Netherlands, Spain, Switzerland, Tunisia, United States of America and the Union of Soviet Socialist Republics.

At the opening session, in addition to the formal business of the Annual General Meeting, reports were received from the various chairmen of the work of the Council and of the standing committees. The latter included the Committee on Manufacture, By-products and Auxiliary Services (Monsieur Papillion), Committee on Gas Purification and Treatment (Monsieur Berthier), Committee on Gas Transmission (Monsieur Amsler), Committee on Gas Distribution (Monsieur Astier), Committee on Gas Utilization (Monsieur Dury), and the Committee on Education and Documentation (Monsieur Coudeville).

In the course of his report, Monsieur Coudeville acknowledged in warm terms the indebtedness of the Association Technique de l'Industrie du Gaz en France to The Institution of Gas Engineers and to the British gas industry for the arrangements made for the works tour in Great Britain of L'Ecole d'Application des Technique Gazières.*

There followed the presentation of a medal to a member upon completion of 50 years' membership, and of prizes to authors of the best papers given at the 77th Conference.

Monsieur Quéret then delivered his Presidential Address, which was entitled " Reflections After 40 Years with the Gas Industry ". Monsieur Quéret took the opportunity to review in a most fascinating manner the developments that had occurred in the French gas industry both prior to and after nationalization during his life in the industry.

At the completion of his Address, Monsieur Quéret was presented by the Directeur Général of Gaz de France with a medal commemorating his 40 years of service.

The first session was concluded with a report, by Monsieur P. Dagault, of the work of the Society for Industrial Gas Development in France and the showing of an excellent film of industrial and commercial gas cooking.

The remaining five sessions were devoted to the presentation and discussion of technical papers and reports including the following :—†

" Determining Balances of the Materials Resulting from Coking Processes, by Means of a Laboratory Retort ", by J. Lahouste and A. Boyer.

" High-temperature Carbonization Matter Balances ", by G. Meimarakis.

" Use of High-temperature Steam-phase Chromatography in the Gas Industry ", by M. Boivin.

" Some Applications of Gas-phase Chromatography Analysis in the Oil Industry ", by A. Thomas and P. Alba.

" An Example of the Start of Production from a Natural-gas Well. Charlas I Drilling ", by P. Fustier.

" Use of Diagraphs for Determining Gas/Water Dividing Levels ", by F. Poimbœuf.

" Nomograms for the Determination of Pressure Losses in Gas Wells ", by G. Montegudet and D. Chantepie.

" Estimation of Gas Strata Reserves ", by J. Verrien and G. Couraud.

" Conversion of a Marischka Gas-producer Installation for the Autothermal Catalytic Reforming of Natural Gas at the Lyon-la Mouche Plant ", by L. Chabrouty and C. Jungbluth.

" Comparative Study of Catalysts Used in the Gas Industry ", by Madame Vignes and Monsieur Cottin.

" Dehydration and Stripping of the Hassi R'Mel Gas ", by J. J. Brut.

" The Supplying of the Lons-le-Saunier (Jura) Gas Works with Local Natural Gas ", by A. Guillobez.

" The Desulphurization of Propane ", by H. Negrerie.

" Contribution to the Study of the Formation, Elimination and Determination of Iron Carbonyl and Nickel Carbonyl Traces in the Gas in the Beynes Underground Storage Reservoir ", by C. Degent and C. Lebras.

" Current Developments in Rust-proofing Methods Using Paint ", by R. Marpon.

" Influence of Cold-drawing on the Index of Brittleness of Steels Used for Gas Transmission Mains ", by R. Martinoni and C. Geoffray.

" Study by the ' A.R.V. ' Computer of Transmission Systems Operating Under Variable Load Conditions ", by F. Regis de Brem.

" Stereographic Table for Short-term Forecasting of Transmission Main Operating Conditions ", by M. D. Souriau.

" Task Examples of a Laboratory for the Control of Gas Transmission Facilities ", by P. Ruault.

" Pneumatic Actuators on High-pressure Gas Pipe Networks ", by E. Groboillot.

" The Compression Stations of the Lacq Gas Transmission System ", by R. Boulletin.

" Servicing Methods on High-pressure Gas Pipelines ", by R. Bourget and M. Ducros and Monsieur Mercier.

" Gas Flow Measurement by Depression Generator. Automatic Correction in Terms of the Pressure, Temperature and Density Quantities ", by B. Le Rat and P. Erard.

" The Experimental Natural-gas Liquefaction and Liquid Methane Storage and Regasification Station Set up at Nates ", by L. Richard and M. Biais.

" Underground Storage of Liquid Methane ", by J. Toche.

" Study on the Tightening of Gaskets in Gas Mains ", by J. Isson and E. Gautier.

" Behaviour of Joint Rubber Rings in the Presence of Conditioning Agents ", by Madamoiselle G. Desnos.

" Insertion of Welded Steel Tube into an Old Cast Iron Main ", by R. Delabaere and C. Riffault.

" Mechanical Testing of Plastic Tubes ", by J. Isson.

" Converting the Limoges Distribution Network to Natural Gas ", by J. Faye and J. Moreau.

" Development of Working Methods and Equipment Used in Gas Changing-over Operations ", by C. Humbert and H. Bodard.

" Research and Observations on the Determination of Gas Interchangeability ", by F. Gebert.

" Stabilizing Natural-gas Flames by Turbulence ", by A. Alix and R. Etanchaud.

" Convection with Chemical Reaction ", by P. Valentin.

" The P.F.O. (Propane-Fuel-Oil) Burner and its Application to Hot-water Central Heating ", by J. P. Liotier and C. Monnet.

" Equipment for the Change-over of Solid-fuel Boilers to Gas ", by D. Deloges.

" Contribution to the Study of ' Se-Duct ' ", by R. Liard and M. Perou.

" Use of the ' Se-Duct ' in Apartment Buildings ", by P. Richalet.

* See *Journal*, June, 1961, p. 445.

† Copies of these papers are available and may be borrowed from the Library of the Institution. It is hoped to include short abstracts of some of these papers in subsequent issues of the *Journal*.

" Study on the Ventilation of Premises in which Gas Appliances Unconnected to Flues are in Operation ", by P. Faudier.

" Utilization of Natural Gas for Electric Melting Furnaces ", by P. Leblanc.

" Natural-gas Injection Tests in a Blast Furnace at the Boucau Works ", by R. Malvaux, J. A. Cordier and J. Reboul.

The programme for the Conference included a number of visits for ladies, and alternative works visits on the last day for members of the Conference. There was also a most enjoyable performance of Breton music and dancing in the Town Hall Square. The band comprised bagpipes, drums and instruments resembling fifes, and the close similarity to Scottish dancing was of particular interest to the British delegates.

Abstracts of Papers

The full text of articles abstracted below may be consulted in the Library of the Institution.

Investigation into the Advantages and Disadvantages of Using Coal, Oil or Natural Gas as Raw Material for Town Gas Production in Germany.

H. Pichler. 8th International Gas Conference, 1961, June, IGU/37-61.

Although about 97·5 per cent of the total town gas supplied in the Federal Republic of Germany is still produced from coal, the use of petroleum products as raw material for gas production is steadily increasing. A variety of processes have been known for some time, and the author discusses their pros and cons in the light of recent development work, with particular reference to (*a*) technical, (*b*) hygienic, and (*c*) economic considerations. The first section reviews recent developments in methods of town gas production from solid, liquid and gaseous raw materials, and gives comparative tables showing the composition and properties of the resulting gas. The second section considers problems relating to carbon monoxide and sulphur in town gas, dust and waste-gas emission, and effluents. In the third section, graphs are given for the cost of plant and of gas into holder in processes using coal, oil and liquefied petroleum gases for gas outputs of less than 3·5 mill. ft³/d and of between 3·5 and 35 mill. ft³/d. The influence of the size and nature of the plant on the economics of operation is indicated.

The Importance to the Gas Industry of the Schwechat Refinery.

A. F. Orlicek. *Gas Wasser Wärme*, 1961, May, 83-88.

Whilst, in the 1930s, more than 75 per cent of the world's fuel requirements were met by coal, this figure is today only about 46 per cent, the remainder being met by oil and gas. Austria has latterly become an oil-producing country, as a result of which it now has to import only about 50 per cent of its fuel requirement as against 70 to 80 per cent some 20 years ago. Other factors contributing to this improvement are the greatly increased production of brown coal, development of hydro-electric power and the electrification of the railways. Coal as raw material for town gas production is also meeting increasing competition from natural gas and oil products. The paper gives a review of the new Schwechat refinery and of its various products, including liquefied petroleum gases. Storage under pressure for about 6,500 tons of propane and butane is being installed at the refinery, partly in the form of spherical holders. The latter, whilst less costly than cylindrical holders, are still not free from objection, and it is suggested that storage of liquefied petroleum gases at atmospheric pressure and a low temperature would meet all requirements much more economically than storage under pressure, and should be more closely studied.

Calculation of Pipelines and the Pre-requisites for Choosing Optimum Gas Transmission Conditions.

A. V. Alexandrov, B. V. Barabash, I. E. Khodanovich. 8th International Gas Conference, 1961, June, IGU/46-61.

The determination of optimum conditions for ensuring minimum expenditure on the construction and operation of gas transmission systems depends on precise calculation of pipeline capacity and on an analysis of basic and interdependent factors such as diameter, wall thickness, initial pressure, rate and power of compression, distance between compressor stations, *etc.* The authors deal with the calculation of gas flow in pipelines and establish empirical relations for flow resistance factors in pipes and specials and for gas compressibility as a function of pressure. Equations have been obtained relating transmission changes of pressure and throughput with time ; the difference between theoretical and experimental results do not exceed 2 per cent for pressure and 8 per cent for throughput. The influence of solid or liquid suspensions in the gas flow upon the gas pipeline transmission capacity is also considered. The analysis of basic and interdependent factors given in the paper, in mathematical and diagrammatic form, enables the optimum conditions for gas transmission to be calculated.

Report of the Committee for the Study of Safety Conditions in Domestic, Commercial and Industrial Gas Installations.

8th International Gas Conference, 1961, June, IGU/5-61.

The Committee has collated statistics of accidents due to town gas in different countries, and finds that their number represents a very small proportion of the total number of accidents from all causes. Accidents due to mechanical failure of gas mains and service pipes are comparatively insignificant, as are accidents in commercial and industrial gas installations. The greatest number of fatalities, where manufactured gas is distributed, is due to the escape of unburnt gas in domestic premises, the appliance principally involved being the gas cooker, and the commonest cause of escapes being the opening of a gas tap without igniting the gas. Reference is made to the problem of elderly and handicapped persons, and the importance of the provision of automatic ignition devices on appliances is stressed. Other matters reviewed in the report are legal requirements, specifications and codes of practice in regard to the safe utilization of gas, requirements for the flueing of different appliances, odorization of town gas, and the desirability and practicability of reducing the carbon monoxide content of town gas. Recommendations are made in regard to these matters, with a view to reducing still further the accident hazard.

Report by the International Committee for the Harmonization of Essential Clauses in the Specifications for Stamping of Gas Appliances.

8th International Gas Conference, 1961, June, IGU/2-61.

The Committee has completely revised its previous findings, as reported to the 6th International Gas Conference in New York in 1955, and has extended the scope of its enquiry. Accordingly, the recommendations of the present report supersede those of the earlier report. The report comprises a number of individual reports giving detailed recommendations, based on practice in different countries, in regard to general technical clauses (A. Böhm and E. Bertini), water heaters (J. Beyderwellen and A. van der Linden), cooking appliances (P. Delbourg and R. Dury), central heating boilers (van der Haegen and Lejeune), independent heating appliances (F. Schuster and Bitzer), washing machines (P. Delbourg), gas refrigerators and warm air heaters (L. Andrew). Certain data are included relating to the stamping of appliances using liquefied petroleum gases, but no recommendations are made in this connexion. The Committee has maintained close touch with its sister Committee dealing with the interchangeability of gases.

" Modern Resin ' Kitchen ' Ups Output, Cuts Costs "

W. H. Lerstad. Industrial Gas (U.S.A.), 1961, May, 10-12.

Comparative field-tests have been made over an extended period between gas-fired radiant heating settings and conventional oil-firing for batch-cooking kettles for the processing of resins, oils and alkyds. The gas-fired radiant settings showed an increase in

production capacity of 50 per cent per kettle, together with 50 per cent savings in fuel. An accelerated heating rate is achieved by a combination of controlled rate of uniform heating and close proximity of the kettle to the heat source. The cluster of burners also provides an exceptionally wide range of heat input, from 145,000 to 2·8 mill. Btu/h per kettle. In addition to the easy and precise temperature control possible at each step of an operation with the electronically instrumented system, enabling the operator to comply instantaneously with changing demands, the burners can also be set to shut-off at a predetermined time. Alternatively, the system is capable of holding a high level of temperature within a few degrees for a prolonged period. With the new radiant settings, maintenance costs have been greatly reduced as compared with those for the former oil-fired flame-type batch-cooking units.

Personal Notes

Appointments

(*a*) *By Area Gas Boards:*

SCOTTISH GAS BOARD
Coke Technical Officer : **J. C. Macdonald**

WEST MIDLANDS GAS BOARD
Hinckley District—
Assistant Engineer : **P. N. Walker**

NORTH THAMES GAS BOARD
Chief Draughtsman : **T. Green**

(*b*) *General:*

Mr. D. A. B. Llewelyn (M) has resigned his position as Deputy Chief Scientific Officer and Director of the Oil Synthesis Branch, Ministry of Power, to join the Research and Technical Development Department of the British Petroleum Company, Limited.

Mr. E. F. Surti, B.Sc. (AM) has recently taken up the appointment of Assistant to the Superintendent of the Energy and Economy Department of the Tata Iron and Steel Company, Limited, Bihar, India.

Retirements

Mr. W. Kay (M) has retired from his position as Chief Draughtsman of the North Thames Gas Board.

Mr. C. H. Woodfine (M) has retired from his position as Engineer and Manager of the Wellington District of the West Midlands Gas Board.

Addresses Required

The Council would be grateful to receive the present addresses of the following members, last heard of in the places given in brackets :

Mr. W. G. Bignell (Eastbourne).
Mr. E. Clark (Bridlington).
Mr. S. W. Hayes (Braunton).
Mr. D. Helliwell (Halifax).
Mr. P. W. Hugh (Middlesbrough).
Mr. C. Kay (Cambridge).
Mr. N. P. Shepherd (London).
Mr. A. W. Somerville (Bury).
Mr. A. M. Steel (Gutersloh, Germany).
Lt.-Col. T. C. Whimster (Ashford).

Institution Register

Transfers

To Companionship :

Aird, Peter Douglas Miller, T.D., London.
Alexander, John Russell Willis, C.B.E., M.A., LL.B., London.
Johnson, Richard Stringer, M.B.E., T.D., M.A., LL.B., Leicester.
Jones, Thomas Mervyn, C.B.E., M.A., Cardiff.
Leach, Charles Harold, M.A., Southampton.
Milne-Watson, Michael, C.B.E., M.A., London.
Oatley, Arthur Frederick, Tettenhall.
Welman, Douglas Pole, Manchester.

Deaths

The Council regrets to announce the death of the following members of the Institution:

(*a*) *Honorary Member:*

Smith, Arthur William, C.B.E. (Birmingham) HM.1936 ; died 9th June, 1961.

(*b*) *Members:*

Knowles, Alan Francis Horner, B.Sc. (Cowley Peachey) M.1950 ; died 5th June, 1961.

Nichol, Harold (Hull) M.1955 ; died 14th May, 1961.

Pegg, Ernest Edward (Ilford) M.1939 ; died 25th May, 1961.

Simpson, John Findlater, M.A., B.Sc. (Scunthorpe) M.1928; died 14th July, 1961.

Voss, Walter Arthur Stackling (Rayleigh) M.1946; died 4th July, 1961.

(*c*) *Associate Members:*

Magson, John Hewitt Hockey (Dover) AM.1947 ; died 29th May, 1961.

Woodcock, Jack (Colwyn Bay) AM.1943 ; died 29th June,1961.

District Sections and Affiliated Associations

(a) Notes of Meetings

DISTRICT SECTIONS

Eastern Section

(*a*) Members of the Institution's Eastern Section met on 26th April, 1961, to inspect the first "M.S." (micro-simplex) reforming plant to be erected in Great Britain, which is now nearing completion at the Cambridge Gas Works of the Eastern Gas Board. Among those present were:—Mr. F. T. Brookes, M.B.E. (Deputy Chairman, Eastern Gas Board); Mr. H. S. Cheetham (President, The Institution of Gas Engineers); Mr. J. Hunter-Rioch, M.B.E. (General Manager, Cambridge Division, Eastern Gas Board); Dr. W. T. K. Braunholtz, O.B.E. (Secretary, The Institution of Gas Engineers); Mr. Bernard Clarke, M.B.E., J.P. (General Manager, Lincolnshire Division, East Midlands Gas Board); Mr. E. O. Rose (Chief Engineer, Eastern Gas Board); Mr. R. Whiting (General Manager, Ipswich Division, Eastern Gas Board); Mr. H. R. Hazeldine (Chief Accountant, Eastern Gas Board), and Mr. J. T. Brookes (Manager, Norwich Division, Eastern Gas Board).

Morning arrangements included not only an inspection of the new plant, but an extensive conducted tour of the works with special attention to points of particular interest. A brochure was produced for the occasion.

Though this system of gas manufacture was invented by Stein et Roubaix, of Paris, about seven years ago, and has been used with success in France, the Cambridge installation includes many modifications and improvements and was built by Woodall-Duckham Construction Company, Limited, which is the sole licensee for building M.S. units in the British Commonwealth, Eire, South Africa and Scandinavia.

At Cambridge, this process will be used to produce town gas from light petroleum distillate, enriched with propane/butane. It could also be used for the treatment of natural gas.

In building this plant, many unusual problems have been overcome, not least in connexion with safety and fire control.

Briefly, the method of operation is that light petroleum distillate vapour is injected with air and steam into the top of a hot generator, where thermal cracking takes place: the mixture then passes directly through a hot nickel-impregnated catalyst bed where the reformation to gas is completed. The gas then passes through a waste-heat boiler that uses a high proportion of the sensible heat, and is then cooled further and cleaned in a wash box with its own tower scrubber, and finally in a tower common to both units.

Duplicate vaporizers are installed to provide propane/butane vapour for enriching the reformed gas, the final gas being very similar to normal town gas.

There are two reforming sets at Cambridge.

Automatic operators and control equipment, together with the "make" and "heat" blowers, boiler feed pumps and control air units, are housed in a sound-proofed building, whereas the gas-making and washing vessels stand in the open. The operators are fitted with heated air blowers that serve to keep the units dust- and moisture-free; they are especially useful during long periods of shut-down when the electronic equipment might otherwise suffer from dampness.

Plant operations are electrically actuated through micro-switches that control the movement of pneumatically operated cyclic valves.

Safety devices and interlocks are provided that shut down the reactors if necessary.

Gas-making capacity at Cambridge consists of 3 mill. ft^3/d from continuous vertical retorts, and 6 mill. ft^3/d of carburetted water gas. Each of the M.S. sets can make just over 1 mill. ft^3/d to give a total works capacity of 11·2 mill. ft^3/d.

The M.S. plant has been constructed on the site of an early horizontal retort house, which ceased to make gas four years ago.

Much special construction work has been necessary to conform with fire and safety regulations; the very large quantity of water that must be available for first-aid fire-fighting, which, together with cooling water, is equivalent to three times the normal load for the whole works, has necessitated the installation of large-capacity pumps and pipelines as well as the construction of new water offtakes from the River Cam.

Other examples of fire prevention precautions are the construction of storage vessels not less than 25 ft from one another and 50 ft from any other building, elimination of openable windows and doors facing the petroleum tanks, and the necessity of the tanker unloading bay being so designed that the contents of one compartment of a road tanker can be confined within its base in the event of it inadvertently emptying on to the ground.

To replace the steam production capacity from the waste-heat boilers in the recently discontinued intermittent vertical retort house, and also to replace three obsolete Lancashire boilers, three packaged vertical boilers have been installed: these are oil-fired.

The Eastern Gas Board entertained the inspecting party to luncheon, when Mr. F. T. Brookes, M.B.E., Deputy Chairman, proposing the toast of "The Eastern Section," conveyed greetings and best wishes for a successful meeting from the Chairman of the Board (Mr. J. H. Dyde, O.B.E.). He said that the Section had, under one title or another, been in existence for 73 years and had done an "excellent job of work."

Welcoming Mr. H. S. Cheetham (President of The Institution of Gas Engineers) who had been a member of the Section for more than 30 years, the speaker said that he had carried out his duties with dignity and distinction.

It was also a matter for pride that Mr. T. C. Battersby, M.B.E., who was to succeed to the Presidential office of the parent Institution, was also a member of the Eastern Section.

In addition, the Section enjoyed the reflected honour of Mr. Bernard Clarke's appointment as Sheriff of Lincoln, the first time, it was believed, that a gas engineer had held such an office.

Mr. Brookes continued, by testifying to the real and earnest spirit of friendship that had been characteristic of the Eastern Section since its formation, resulting in a comradeship as they met together for sharing experiences and learning something of the problems which had to be met by the gas industry. "I know of no gathering of people from whom I have drawn more in friendship and encouragement than the Eastern Section," said Mr. Brookes, and went on to urge that they should continue in this way and do everything possible to strengthen the membership, which would have gained considerably during the past year but for an unusual number of deaths and retirements.

Describing Mr. E. H. Winch, the Section's Chairman, as a "perfectionist" and one dedicated to his job, Mr. Brookes mentioned the qualities and achievements of Mr. Winch, who was the architect of the Cambridge Divisional control system, which had formed the subject of his paper to the annual meeting a year or two ago. Indeed, the contribution he had made was a most worthy one.

Mr. E. H. Winch, responding to the toast, recalled how the Cambridge works had changed since the Eastern Section visited the Newmarket Road works in 1946.

The Section had also made considerable advances and derived benefit as membership had been extended. They were, he said, all very jealous of the Eastern Section's reputation for friendliness, which had been fostered by Mr. J. Hunter-Rioch, M.B.E., and he hoped that it would continue.

He expressed pleasure at the attendance of the President of The Institution of Gas Engineers, Mr. H. S. Cheetham, at the meeting.

Thanks were due to all who had contributed to the works visit, the guides, technical staff and, particularly, the engineer (Mr. W. J. Spiller) and his assistant (Mr. W. Bolton).

Mr. H. R. Hazeldine, the Eastern Gas Board's Chief Accountant, occupied the afternoon session with an account of the accounting functions in the gas industry. The functions of an Area Board Chief Accountant the speaker defined as the recording of all the financial transactions and the production of the annual revenue account and balance sheet; he was the treasurer of all the Board's moneys, and responsible for the production, presentation and interpretation of financial and statistical information as an aid to management, as well as for advising the Board on financial matters.

A lively discussion developed, and a number of questions were submitted which enabled Mr. Hazeldine to clarify certain points and to amplify some matters which needed further explanation.

In proposing a vote of thanks to Mr. Hazeldine for his paper, Mr. Hunter-Rioch, M.B.E., said he was pleased to do this because it gave him the opportunity of paying tribute to the work done by the accountants in a nationalized industry. There was every justification for placing a high priority on the work of the accountant because of the urgent need for proper books of accounts and statistics. He stressed the importance of close liaison between accountants and other functional officers, and expressed pleasure that in the Cambridge Division of the Eastern Gas Board mutual problems were discussed freely and amicably, to the ultimate advantage of the Board.

Two new members were admitted. Members, too, had the opportunity to join in congratulating Mr. R. F. Clarke and Mr. C. E. Peek, of Norwich, who were presented with Institution of Gas Engineers certificates by Mr. H. S. Cheetham (President of the Institution).

Tribute was paid to the memory of Mr. C. D. Birks and Mr. R. B. Glover, who had been members of the Eastern Section.

(*b*) The 11th Annual General Meeting of the Eastern Section was held at Great Yarmouth on 2nd and 3rd June, 1961.

The meeting was preceded by tournaments at which the Turner Golf Trophy was won by Mr. K. B. Meggitt, and the George Wright Golf Cup by W. W. Paterson. The Fred Wilson Bowls Cup went to Mr. W. A. Pask, and the Derrick Wilson Bowls Cup to Mr. H. Wadsworth.

The Annual General Meeting opened with a civic welcome by his Worship the Mayor of Great Yarmouth (Alderman E. Barker), which was acknowledged by Mr. E. H. Winch (Chairman), who also greeted in turn Mr. T. C. Battersby, M.B.E., (President of The Institution of Gas Engineers), who was the second member of the Eastern Section in succession to hold that office; Mr. J. H. Dyde, O.B.E. (Chairman, Eastern Gas Board); Mr. A. G. Higgins, (Secretary, The Institution of Gas Engineers), and Mr. F. J. Martin (Secretary, Eastern Gas Board). This was the first District Section meeting that the new President and new Secretary of the Institution had attended since they assumed office.

A number of apologies for absence were received, and a cordial welcome extended to seven new members.

Sympathetic reference was made to the death of Mr. J. F. Simpson, Scunthorpe, who had been a member of the Section since 1922, and a silent tribute paid to his memory.

Mr. K. B. Meggitt, Bedford, was elected Chairman; Mr. D. W. Ault, Lincoln, Senior Vice-Chairman, and Mr. W. A. Pask, Grimsby, Junior Vice-Chairman. Mr. D. B. Parkinson, M.B.E., and Mr. K. C. Rees, both of Watford, were elected to be ordinary members of the Management Committee. Mr. J. Hunter-Rioch, M.B.E., Cambridge, was re-elected Honorary Secretary and Treasurer, and Mr. A. W. Mather, Ipswich, and Mr. H. H. Redwood, Newmarket, will continue as auditors.

The Management Committee, in its annual report, reviewed another successful year. The net increase in the membership was only slight, since deaths and retirements had offset the 10 new members.

Mr. J. Hunter-Rioch, M.B.E., reported that the year's working showed a credit balance of £25 8*s.* 5*d.*, and the Chairman's Benevolent Fund an increased balance of £15 14*s.* 1*d.* The accounts were adopted, and a donation of £15 made to the Benevolent Fund of The Institution of Gas Engineers.

Mr. T. C. Battersby, M.B.E., acknowledged the donation, on behalf of the Institution, and referred to the many cases that required assistance and to the way in which the Fund was trying to meet them.

Mr. E. H. Winch then delivered his Chairman's Address.

Mr. D. B. Parkinson, M.B.E., proposed a vote of thanks to the Chairman, and spoke of Mr. Winch as a valued, able and competent colleague and one who was thorough in all he undertook. These qualities, he said, were reflected in the Address. Mr. W. A. Pask seconded the vote of thanks.

At a civic reception held at the picturesque Town Hall in the evening the guests were received by the Mayor and Mayoress and by Mr. and Mrs. E. H. Winch.

On the morning of 3rd June, Mr. J. H. Dyde, O.B.E., Chairman of the Eastern Gas Board, spoke on "Improving our Competitive Position".

Mr. Dyde was thanked by Mr. R. Whiting, who described the address as "a Chairman's eye view of the industry", covering a wide field in a comprehensive manner and enabling members to be kept in touch with the Chairman's thinking. It provided an enlightened and comprehensive review of the industry's current position. Mr. D. W. Ault, seconded the vote of thanks.

At the close of the meeting, Mr. Winch introduced Mr. K. B. Meggitt, the Chairman-Elect, and extended best wishes to him, with the hope that his term of office would prove most enjoyable.

While members were attending the meeting, Mrs. E. H. Winch was the hostess at a ladies' coffee party. At its conclusion Mrs. Winch was thanked by Mrs. Meggitt, wife of the Chairman-Elect.

An official Luncheon brought the meeting to an end. Among the guests were the Mayor and Mayoress of Great Yarmouth; Mr. Farra Conway, Town Clerk, and Mrs. Conway; Mr. J. A. Kinnersley, Director, Publicity Department, and Mrs. Kinnersley; Mr. T. C. Battersby, M.B.E. (President, The Institution of Gas Engineers), and Mrs. Battersby; Mr. J. H. Dyde, O.B.E. (Chairman, Eastern Gas Board) and Mrs. Dyde; and Mr. J. A. Beckett, C.M.G., Under Secretary (Gas), Ministry of Power; Mr. A. G. Higgins, Secretary, The Institution of Gas Engineers; Mr. A. S. H. Dicker, Member of the Eastern Gas Board, and Mr. F. J. Martin (Secretary, Eastern Gas Board) and Mrs. Martin.

The Loyal Toast having been honoured, Mr. W. G. Phillips proposed the toast of the County Borough of Great Yarmouth and its Mayor. He referred to the independent character inherited by the people of Great Yarmouth, which was reflected in their opposition to the proposals of the Boundary Commission, which threatened to deprive them of their county borough status. A review of the long history of Great Yarmouth showed it as a place of great antiquity, which had played a great part in the pages of "the glorious history of our country". Yarmouth today was a busy, prosperous and progressive town, with up-to-date houses and developing industries, apart from its traditional fishing. In all this development, the Eastern Gas Board had been proud to be associated, particularly in connexion with the recent provision of homes for the elderly, where warm-air heating and water heating had been introduced. The Board was jealous of the happy relations it enjoyed with the local officials.

Mr. Phillips also paid a warm tribute to Mr. John Greenacre as one greatly honoured in the district—"a rugged individualist", "a friend and colleague"—whose tragic death occurred last year, when the Board lost a "very valued senior official".

In reply, Alderman E. Barker, "proud to be the Mayor of this wonderful town", commented on the varied nature of the associations he had entertained, and said that both the Mayoress and himself had enjoyed the company of the gas engineers.

"The Guests" were toasted by Mr. K. B. Meggitt: Mr. J. A. Beckett, C.M.G., who was representing the Ministry of Power at the Eastern Section's Annual General Meeting and followed several distinguished predecessors; Mr. J. H. Dyde, O.B.E., who had been a staunch supporter of the Section since Vesting Day, and whose erudite and polished speech that morning had proved most interesting to all; and Mr. T. C. Battersby, M.B.E., in the reflected glory of whose office as President of the parent Institution the Section could bask. Mr. Meggitt welcomed also the ladies, whose presence had made what might have been merely a business meeting a "glittering social occasion", and hoped they would long continue to attend the Annual Meeting of the Section.

In reply, Mr. Beckett testified to the Ministry's admiration for The Institution of Gas Engineers and its activities, and said the Eastern Section set a standard that it would be hard to beat. The Institution as a central body stood very high in this country, he said, but it was its association with the gas industry as a whole that really mattered.

Discussing the work of the Ministry of Power, Mr. Beckett said that at present there were before the Minister many matters of high import affecting the gas industry. After a passing reference to methane, Mr. Beckett expressed his belief that the Institution, which reached its centenary in two years' time, would have a greater rôle to play in the next few years than ever before. For a long time, it had operated on a pretty conservative basis, but a change was coming, and gas engineers must face up to the challenge. As a great believer in gas, he saw a tremendous future for the industry, particularly when he discovered recently that one Board had achieved more than 7 per cent increase in its domestic gas consumption in the last financial year. "You have a great opportunity to get ahead," concluded Mr. Beckett, "and it is you who are going to be right in the van of this transition from a good, old, basic industry, which no longer has a monopoly, to something dynamic and new".

Mr. T. C. Battersby, M.B.E., President, The Institution of Gas Engineers, gave the toast of "The Eastern Section" and said that the strength of the Institution depended to a large extent upon the strength of its District Sections, of which the Eastern Section was a virile and lively example. Complimenting the Chairman on the papers that had been presented during the year, and on the manner in which the scope of the platform had been extended, Mr. Battersby stressed that District Section meetings should not be confined to the subjects of carbonizing and purification, because in these days many professions were engaged in producing gas for the consumer.

Mr. Battersby congratulated Mr. Hunter-Rioch, M.B.E., the Honorary Secretary and Treasurer of the Section, and his staff on the excellence of the arrangements throughout the year, culminating in the Annual General Meeting. He recalled also that Mr. Hunter-Rioch had been responsible for the formation of the Eastern Junior Gas Association, which had emerged as a fledgeling and was now flying on its own.

After acknowledging the Section's contribution to the Benevolent Fund of the Institution, Mr. Battersby appealed for many more Associate Members, who possessed the necessary qualifications, to apply for full Membership of the Institution.

In a tribute to the Section's Chairman, the speaker said that the guidance of Mr. Winch had been enjoyed throughout a wonderful term of office, and it was to be hoped that Mr. Meggitt, the succeeding Chairman, would have as pleasant and successful a year.

Mr. E. H. Winch, returning thanks in what he described as his "swan song", said its members were very proud of the Eastern Section, and particularly so on this occasion because Mr. Battersby was the second successive member of the Section to become President of the Institution. The Section was indebted to the parent institution for its continual support, as it performed a tremendous amount of work on behalf of the industry and its members.

The reputation the Section enjoyed for its friendliness, particularly at its Annual General Meeting, was due, he

said, to the care and influence exerted by Mr. Hunter-Rioch.

Mr. Winch thanked the Mayor of Great Yarmouth for all that the borough had done to make the Section's visit so successful and enjoyable; also Mr. Farra Conway (Town Clerk) and Mr. J. A. Kinnersley (Director of Entertainments) for their co-operation, and all who had in any way contributed to the pleasure of the Eastern Section's visit to Great Yarmouth.

South Western Section

The South Western Section's Summer Meeting and Ladies' Day, held on Wednesday, 28th June, 1961, and centred on Torbay, was attended by 87 members, ladies and guests.

The morning's proceedings included a visit of members to the Hollacombe manufacturing station of the South Western Gas Board, whilst the ladies were entertained to coffee by Mrs. T. W. Jackson, at the Redcliffe Hotel, Paignton.

Luncheon was also taken at the Redcliffe Hotel, and Mr. T. W. Jackson (Chairman of the Section), proposed a toast to the ladies and guests and expressed his pleasure at the attendance of so many members and their ladies. Mrs. Jackson responded on behalf of the ladies and guests.

During the afternoon, members and guests embarked on "Western Lady", at Princess Pier, Torquay. The occasion was favoured with perfect weather conditions. The vessel, chartered exclusively for the trip, cruised along the coast to the River Dart, and interesting landmarks included Dartmouth Naval College. Tea was taken on board, and the vessel turned for home off Dittisham.

JUNIOR GAS ASSOCIATIONS

Manchester District Junior Gas Association

The Ladies' Day meeting of the Association was held on 10th June, 1961, when the President, Mr. J. A. Taylor, and about 120 members and ladies visited Chatsworth House and gardens and were afterwards entertained to tea at the St. Anne's Hotel, Buxton, by invitation of Mr. A. H. Nicholson, General Manager, Manchester Group, North Western Gas Board.

Following tea, Mr. G. Gilden (Production Engineer, Manchester Group) apologized for the unavoidable absence of Mr. Nicholson, and extended a warm welcome to the visitors.

The President expressed the thanks of the Association to the Manchester Group for the excellent arrangements made for the visit and for the hospitality provided.

Mr. W. F. Howell (Senior Vice-President), addressing the ladies, said how delighted the members were in their presence at the meeting. One of the advantages of Ladies' Day was that, at least, it proved to the ladies present that the Association really did exist! He hoped that they were enjoying the proceedings.

Miss A. Livesey replied briefly on behalf of the ladies.

The occasion ended with an informal dance.

Northern Junior Gas Association

The Annual General Meeting of the Association was held, on 16th June, 1961, at the Demonstration Theatre, Gas Showrooms, Stockton-on-Tees.

Before the formal meeting, more than 74 members met for luncheon at the Vane Arms Hotel, at which Mr. G. E. Haddon (Distribution Engineer, Northern Gas Board), President of the Association, welcomed guests who included Mr. L. A. Garratt (Industrial Relations Officer, Northern Gas Board), Mr. J. E. McManus (General Manager, Blyth Division, Northern Gas Board), Mr. C. Hindle (representing Mr. F. Wilson, General Manager, Darlington Division), Mr. L. Nelson (Blyth), Mr. F. J. Webster (representing Mr. W. Sutcliffe, General Manager, Tyneside Division) and Mr. Greenfield (representing Mr. H. Buckley, General Manager, Tees-side Division).

Mr. L. A. Garratt, who replied on behalf of the guests, said that the future of the gas industry was assured and that the younger members of the Association should realize the great opportunities within the industry, especially in gas distribution and gas utilization.

The Annual General Meeting opened with apologies for absence from Mr. E. Crowther, C.B.E., and Mr. J. E. White (Chairman and Deputy-Chairman respectively of the Northern Gas Board), Mr. W. R. Garrett (Constructional and Consultant Engineer to the Board), Mr. R. S. Longhurst (Carlisle), Mr. K. E. Brown (Newcastle-upon-Tyne), Mr. F. Wilson (Darlington) and Mr. J. C. Graham (Gateshead-upon-Tyne).

The President then referred to the valuable service rendered by Mr. Bob Proud as Honorary Secretary of the Association, and regretted Mr. Proud's relinquishment of that appointment on account of ill-health.

The minutes of the Annual General Meeting held in 1960 were read, and confirmed on the proposition of Mr. R. J. K. Shepherd (Carlisle), seconded by Mr. W. R. Elliott (Newcastle-upon-Tyne).

The Honorary Treasurer's report was submitted by Mr. C. H. Ling (Darlington), and accepted on the proposition of Mr. S. G. Irvin (West Hartlepool), seconded by Mr. W. Cummings (Newcastle-upon-Tyne).

The Transactions Secretary's report was presented by Mr. R. J. K. Shepherd.

The Presidential Address, by Mr. G. E. Haddon, was for the first time in the Association's history delivered through loudspeakers from a tape recorder.

A vote of thanks to the President was proposed by Mr. J. T. Lewis (Sunderland) who said how important the President's Address was in dealing with safety measures within the gas industry. Mr. Lewis remarked on the success of the President's innovation in tape-recording his Address.

The election of officers for 1961-62 resulted as follows:—President, Mr. L. Nelson (Blyth), Senior Vice-

President, Mr. J. R. Matthew (Shotley Bridge), Junior Vice-President, Mr. J. T. Lewis (Sunderland), Honorary Secretary, Mr. S. G. Irvin (Newcastle-upon-Tyne) Honorary Treasurer, Mr. C. H. Ling (Darlington), and Honorary Transactions and Publicity Secretary, Mr. R. J. K. Shepherd (Carlisle).

Mr. G. E. Haddon, the retiring President, invested Mr. L. Nelson with the Badge of Office as new President.

Presentation of the Society of British Gas Industries Silver Medal was made by the President to Mr. G. Taylor (Newcastle-upon-Tyne).

The presentation of certificates to the retiring President, Mr. G. E. Haddon, was made by the President, Mr. L. Nelson.

Mr. Haddon, replying, said he had enjoyed his year of office and thanked members for their support. He regretted that his year as President had included the retirement of Mr. Bob Proud as Honorary Secretary, due to ill health. He thanked Mr. Ling for carrying on the duties of Acting Secretary to the Annual General Meeting.

A vote of thanks to the Officers, Members of Council and Honorary Auditors of the Association was proposed by Mr. V. R. Burrows.

Following the Annual General Meeting, members were entertained to tea, and thanks for hospitality were given to Mr. H. Buckley (General Manager, Tees-side Division, Northern Gas Board).

Western Junior Gas Association

(*a*) About 60 members of the Association visited Torquay on Saturday, 13th May, 1961, when they toured the Hollacombe manufacturing station of the South Western Gas Board. Members had an opportunity to see the more recent developments on the works, including primary flash distillate storage and unloading arrangements, primary flash distillate installation on continuous vertical retorts, and also preliminary work on the new coke-bagging installation for the packaging of "Gloco", *etc.*

Following the works visit, the visitors adjourned to the Demonstration Theatre at Union Street, Torquay, where they saw two films: the South Western Gas Board's "Operation Sharpness", followed by Land and Marine's "The Severn Incident." "Operation Sharpness" featured the construction of a temporary pipe-line to supply the Forest of Dean area, following the severing of the 12 in. high-pressure main supplying the area from Gloucester.

A brief discussion took place, during which questions raised by members were answered by Mr. J. A. Newton, a member of the Chief Technical Officer's staff, and Mr. R. Pratt, Distribution Engineer, Cheltenham/Gloucester.

The second part of the afternoon meeting was introduced by the President (Mr. F. Tweedle), who stated that it was an innovation in that he proposed to ask two members to open a discussion on two points of current interest, which would be followed by a general discussion of these topics by members. Mr. L. A. Ross (Bristol) then spoke on "Sulphur Removal", which was followed by a lively discussion to which Mr. D. H. P. Hammond, Mr. E. E. Taylor, Mr. L. C. Bennett, Mr. F. G. Craxford and Mr. P. Trevelyan contributed.

Mr. J. J. Long (Exeter) opened a discussion on "Gas in Relation to Competitive Fuels", to which the contributors included Mr. J. Bowler, Mr. J. W. Dean (Regional Engineer and Manager), Mr. W. E. Baggs and Mr. F. G. Craxford.

The meeting concluded with a vote of thanks by Mr. W. E. Baggs (Bath) to all who had contributed to the success of the day's meeting, including Mr. D. J. Maunder (Works Engineer and Manager, Hollacombe), Mr. Oliver Pincock (District Engineer and Manager, Torquay) and Mr. J. W. Dean (Regional Engineer and Manager).

(*b*) The Summer Meeting and Ladies' Day was held on Saturday, 17th June, 1961, when following a morning visit to the Bath manufacturing station of the South Western Gas Board, members and their ladies assembled at Fortt's Restaurant, Milsom Street, Bath, for luncheon.

The President, Mr. F. Tweedle (Bath) welcomed the ladies on behalf of the Association and thanked them for their support, without which the Association's activities would be considerably restricted. He welcomed Mr. A. G. Higgins (Secretary, The Institution of Gas Engineers) on his first visit to the Association in his new official capacity; also Mr. T. W. Jackson (Chairman, South Western Section of The Institution of Gas Engineers) and Mrs. Jackson.

After luncheon, the party travelled by coach to the Forestry Commission's arboretum at Westonbirt, near Tetbury, where they spent an interesting afternoon viewing what is probably one of the finer collections of trees and flowering shrubs in the country.

The day's activities concluded with tea at the Hare and Hounds at Westonbirt.

(b) Abstracts and Discussions of Papers

Copies of the complete papers abstracted below are available for consultation or loan in the Library of the Institution.

DISTRICT SECTIONS

Eastern Section

"Chairman's Address: 1961", *by E. H. Winch, M.I.Gas E., M.B.I.M., A.M.I.Chem.E., Engineer, Cambridge Division, Eastern Gas Board.*

Address delivered at Great Yarmouth on 2nd June, 1961.

The Address describes and comments upon the developments in the Cambridge Division of the Eastern Gas Board during the 12 years that have elapsed since Vesting Day.

The production capacity in 1949, when there were 19 undertakings, was 18·87 mill. ft^3/d. By May, 1961, it had increased to 26·8 mill. ft^3/d, with only five production stations, all linked by a grid mains system and supplying 15 holder stations.

During the period, many changes in production plant have been made to meet increased peak demands at Cambridge, Bedford, and Peterborough, the three largest works, at all of which additional water gas plants were installed.

Consideration was given to the installation of additional production plant at Cambridge, and the steam pressures on the works were raised to 180 lb/in^2 as new plant was installed; the final step was taken in 1961.

The reasons for the closing down of a static vertical retort house at Cambridge, and for the selection of an M.S. ("micro-symplex") catalytic reforming plant to take its place, are given in the Address; also the steps taken to replace the loss of waste-heat steam production following the closing down of the retort house.

Reference is made to a "10-year plan of development" drawn up in 1952; the changes subsequently found to be necessary are discussed. The 10-year plan was principally concerned with the divisional integration scheme for linking together gas production stations and supplying the holder stations. The development of the grid up to its completion in 1959 is described, and some information given of the costs.

The effect of integrated production on the cost of gas made is shown.

The changes in the pattern of organization of the engineering function in the Cambridge Division of the Eastern Gas Board, covering both gas production and distribution over the 12 years from Vesting Date until the present time, are described, and an indication is given of the proportion of capital expenditure in the Cambridge Division during that period under classified headings within the engineering function.

London and Southern Section

"Gas Production: Progress and Problems", *by J. A. Hepworth, B.Sc., M.I.Gas E., Chief Engineer, North Thames Gas Board.*

Chairman's Address delivered in London on 9th May, 1961.

Mr. Hepworth's Address reviews the present position of gas production and possible future developments: it mentions that comment has been made that progress during the past 40 years has been dormant, but that if consideration were given to the events in this period, development would be found to have been very significant. This period of 40 years is divided into two parts of 20 years each—1919 to 1939 and 1939 to 1959. In the former period the Address surveys the progress made from carbonization in horizontal retorts to that in modern continuous vertical retort installations and coke ovens, with the development of electrification and mechanization of all types of ancillary plant. In the second period of 20 years, which commenced at the post-war period, dilapidated plant had to be replaced and new plant installed to meet the increasing load. Moreover, a new social structure was established with full employment and scarcity of labour. Cost of labour and materials rose speedily while the quantity and quality of coal deteriorated. Again, the electricity industry was expanding and the oil industry was becoming a growing competitor. These factors led to the use of alternative raw materials, and in the last few years of the second 20-year period a number of oil-gasification plants were installed, using a variety of oil products. Thus, over the whole of the 40 years, there had in fact been considerable technical progress, and tremendous efforts had been expended to improve the efficiency and economy of gas production.

The future of gas production is then considered and the opinion expressed that in the future the majority of house-holders will become less and less tolerant of solid fuels and that in consequence the domestic demand for coke would be likely to decrease and the residual demand would need to be met by concentrating on the highest quality of coke.

The developments and trends in the domestic, commercial and industrial fields offer, says the Address, a wonderful opportunity to the gas industry to offer gas as a replacement for solid fuel, but, to be successful, it would be necessary to reduce the cost of gas to the consumer, improve its quality and give to the consumer an even higher standard of service at an economic cost. The future position in regard to the production of gas from coal is reviewed, and the high cost of transport of coal in the south from collieries, the pressure from many quarters to eliminate dust fumes and smells, and the increasing difficulty in obtaining suitable labour, all lead to a reduction in the proportion of gas made from coal, and to an increase in the proportion made from petroleum products.

The operation of existing plant is then surveyed and reference made to the necessity of continual improvement in the quality of gas. In this connexion, the prevention of corrosion by the elimination of sulphur is considered to be of paramount importance, and the opinion is expressed that not only would new plants need to be designed to produce gas low in carbon monoxide, but that it also might become necessary to consider removal of carbon monoxide from plants producing gas by traditional methods.

Of the future of gas production, the opinion is expressed that, at least in the southern part of the country, there is no long-term view for the carbonization of coal, and that, in order to survive, the gas industry must reduce the cost of gas to the consumer to become more competitive with other fuels, and that only by using oil and oil products as feedstocks could gas be made more cheaply than by carbonizing coal.

Reference is made to the use of liquefied petroleum gases as a serious competitor to gas in the commercial and industrial fields, and the Address suggests it would be to the interest of the gas industry to absorb as much as possible of this production to ensure its use as a fuel through the already existing pipe distribution system of the gas industry.

It is pointed out that the use of natural gas or liquid methane could be considered as competitive with home-produced oil products, and that it is desirable that such gas should become available to the industry.

Finally, the requirements of future types of plant are discussed, and, in this connexion, the possibility of a progressive uplift of the calorific value of town gas is mentioned.

JUNIOR GAS ASSOCIATIONS

Midland Junior Gas Association

"A Carburetted Water Gas Holder and Exhauster Control System",

by C. Whitehead, A.M.I.Mech.E., A.M.I.Gas E., Senior Assistant Engineer, Windsor Street Works, Birmingham Division, West Midlands Gas Board.

Paper delivered in Birmingham on 7th March, 1961.

The Author states that, owing to the bad condition of the 100,000 ft³ relief holder at the Windsor Street works, it was decided to replace it by a 20,000 ft³ balancing holder combined with regulating gear for the carburetted water gas exhauster.

At times of maximum gas production the capacity of the new holder is equivalent to only 3·2 min of production, and it was necessary to provide equipment that would ensure safe working of the holder and exhauster.

The exhauster is driven by a steam engine, the speed being controlled by a steam throttle valve.

Pressurized air from the blast main at a governed pressure passes through a needle-valve into a service connecting the space beneath the diaphragm, which operates the steam throttle-valve, and a relief valve operated by the movement of the holder. The relief valve alters the pressure conditions under the diaphragm so that the exhauster speeds up when the holder rises; the operation reverses when the holder falls. The speed of the exhauster is altered as the rate of gas production varies, and the holder is normally maintained at its mid-position.

To safeguard the holder against overpulling, a hanging plate suspended from the crown is arranged to seal the inlet/outlet pipe before the holder settles on the rest blocks.

Striker-plates on the holder side sheeting operate a butterfly valve in a main by-passing the exhauster. The valve opens when the holder is 2 ft from the rest blocks, and closes when the holder is 6 ft above the rest blocks.

A small Connersville air blower, which is belt-driven from the main shaft of the exhauster, supplies the air required for the purification process. Equipment has been installed to prevent a high proportion of air accumulating in the gas stream when the automatic holder by-pass valve is open.

The air from the blower passes along a service containing an orifice plate for measuring the air, a relief valve on a tee-connexion, a diaphragm-operated cut-off valve and a non-return valve, and discharges into the inlet exhauster main.

A supply of pressurized air from the blast main normally holds open the cut-off valve. When the holder reaches a predetermined low level, the supply of pressurized air is shut off and the service vented by a valve operated by striker-plates on the holder. The diaphragm-operated cut-off valve closes and prevents the purification air entering the gas main; this air is then vented to atmosphere through the relief valve. The purification air supply is restored when the holder rises.

The equipment installed ensures (*a*) safe operation of the exhauster, (*b*) safe operation of the balancing holder, (*c*) safe admission at all times of air for the purification process to the gas stream, and (*d*) all controls establish safe conditions if failure of equipment should occur.

Discussion

Mr. B. G. H. Hawkings (Coventry) said that he found the paper interesting, although it described a form of control that was not new. He wondered how the arrangements mentioned by Mr. Whitehead operated when the temperature was low, i.e., what form of anti-freeze control was used?

Mr. Hawkings asked also if the valve and cam-operated spindle on the holder were housed. He considered that the low-pressure regulator shown in Diagram 3 should be called a safety cut-out.

The **Author** replied that the system he had described had functioned throughout the past winter, which was a mild one, but all lines fell to one point, which was run off once each week, and the distance from the plant to the holder was very short. The temperature in the lines was, therefore, seldom very low, and no difficulty had, to date, been experienced with freezing. The cam-operating gear was protected by a sheet-metal cover.

The low-pressure regulator referred to by Mr. Hawkings did in fact operate as a safety cut-out valve.

Mr. C. Halstead (Birmingham) referred to the control that varied the speed of the exhauster to maintain the balancing holder at approximately its mid-position with the air pressure set at 13½ in., and asked it it could be set at a higher pressure.

Referring to the air to the purifiers, Mr. Halstead wondered what type of filter was fitted on the inlet on the air blower.

The **Author** said that the setting of the control was determined by the spring loading of the diaphragm bowl; the lower the control was set the better. There were no filters on the air lines to the purifiers; they had been used initially, but were now considered unnecessary since the blowers worked quite satisfactorily without them.

Mr. G. Cope (Walsall) enquired: "With what speed does the equipment respond?"

The **Author** said that production could be increased to a rate of 375 ft³/h for three machines, and this would still not blow the holder, which took 3 min to fill. The exhauster could pick up from 100 to 350 r.p.m. in a matter of seconds.

Mr. R. W. Nelson asked if the size of the relief holder varied with the size of the plant.

The **Author** replied that the size of the relief holder had no special significance in relation to the size of the plant.

Mr. G. W. Harvey (Walsall) said that steam engines were used at Walsall, and asked if there would be any change in the speed of the exhauster as a result of increased steam demand.

The **Author** said that fluctuations in the demand for steam would have very little effect on the speed of the exhauster, as the control gear would compensate for the drop in steam pressure.

Mr. S. Brockbank (Newcastle-under-Lyme) asked if it would not be safer if air from the blowers did not go through the detarrers?

The **Author** replied that to do this would mean running piping a very great distance.

Mr. S. C. Crathorn (Wolverhampton) pointed out that the control system described in the paper meant that some labour would not be required (i.e., no exhauster drivers would be needed), and asked what had happened to them?

The **Author** replied that these men had been found other work.

Mr. J. Hatfield (Derby) asked how often the control equipment was tested.

The **Author** said that in effect it was always being tested, i.e., by means of the "peep and poke". With three machines working, this meant three times per shift.

Mr. W. E. Dobson (Birmingham) said that the equipment described by Mr. Whitehead was good and of a type such that it should be possible to dispense with an exhauster driver, but he felt that the layout at Windsor Street was against this.

Mr. A. W. Sanders (Birmingham) explained arrangements he had in mind in the event of a breakdown in equipment of this type, using "Askania" control to restrict the flow of gas to the exhauster.

Mr. A. V. Wainwright (Shrewsbury; Senior Vice-President), who proposed a vote of thanks, said that there was a similar system in operation at Shrewsbury, but he felt that Mr. Whitehead had tended to discount the difficulties with freezing. His own experience was, despite Mr. Whitehead's confidence in the equipment, that it might well be liable to breakdown due to freezing during a severe winter.

"A Tower Purifier Charging Programme to Produce a High Sulphur Content Sales Oxide",

by P. H. Valle, Senior Works Chemist, Litchurch Works, Southern Production Region, East Midlands Gas Board.

Paper delivered in Birmingham on 7th March, 1961.

A method of determining an oxide-blending and charging programme suitable for tower purifiers, but applicable to any installation of oxide purifiers, is described, which will result in the production of spent oxide containing 63 per cent of sulphur (d.b.). (It can, however, be used to construct a programme for obtaining any desired sulphur content.)

The calculations rely upon a knowledge of the following facts:

(1) Volume of oxide held in a purifier.
(2) Specific volumes of new and part-spent oxide respectively (as ft³/ton).
(3) Sulphur tonnage to be absorbed from the gas.
(4) The useful sulphur pick-up by tower charges of "all part-spent", and "new plus part-spent", oxide respectively.
(5) Weight of diluent material deposited in the oxide, expressed as a proportion of the elemental sulphur deposited.
(6) The relationship between the sulphur content of an oxide and a maximum water content that it can be expected to support.

At Litchurch the figures relative to items (1) to (6) above are:—

(1) 13,000 ft³.
(2) 50 and 42 ft³/ton.
(3) 2,210 tons, approximately one year's load, yielding 3,900 tons of spent oxide (10 per cent moisture).
(4) 82 and 87 tons.
(5) 24 per cent; i.e., gain in weight for 82 and 87 tons of sulphur deposited will be 102 and 108 tons, respectively.
(6) Sulphur (per cent) on the wet basis = $90{\cdot}5 - 2{\cdot}32 \times$ Moisture (per cent), or Moisture (per cent) = $\frac{90{\cdot}5 - \text{S(per cent)}}{2{\cdot}32}$

The quantity and analysis of the ingoing charge of part-spent oxide, which, on gaining 82 tons of sulphur, can be calculated to be 310 tons and 44 per cent sulphur (w.b.) with 19·7 per cent of moisture, respectively, to produce 390 tons of spent oxide containing 56·7 per cent sulphur (w.b.) with 10 per cent of moisture. To produce 3,900 tons of spent oxide, 10 such charges must be introduced absorbing 820 tons of sulphur between them.

This leaves 1,390 tons of sulphur to be absorbed by 16 charges, which will be blends of new plus part-spent oxide. These blended charges must produce part-spent oxide of the constitution shown above.

Allowing for the gain in weight due to materials other than elemental sulphur (5, above) it can be shown that no more (and no less) than 1,200 tons of new oxide (36 per cent of moisture) can be used. Shared amongst the 16 mixture charges, 75 tons are required for each blended charge.

Using the specific volume figures (2, above) the quantity of part-spent oxide required, 220 tons, to make up a complete charge can be found. By proportions, the overall analysis of a blended charge can be obtained.

The accompanying table shows the input and output required.

Ingoing Blended Oxide				*Outcoming Part-spent Oxide*		
Weight (tons)			Sulphur Gain 87 tons	Weight (tons)		
75 New + 220 P.S. = 295			Weight Gain 108 tons	414 (wetted to 19.7% Moisture)		
Analysis—				Analysis—		
S% (w.b.)	S% (d.b.)	Moisture %		S% (w.b.)	S% (d.b.)	Moisture %
33.4	43.8	23.9		44.9	55.9	19.7

Ingoing Part-spent Oxide				*Outcoming Spent Oxide*		
Weight (tons)			Sulphur Gain 82 tons	Weight (tons)		
310			Weight Gain 102 tons	390 (allowing 10% Moisture)		
Analysis—				Analysis—		
S% (w.b.)	S% (d.b.)	Moisture %		S% (w.b.)	S% (d.b.)	Moisture %
44.9	55.9	19.7		56.7	63.0	10

	IN (tons)		OUT (tons)	
	New	Part-spent	Part-spent	Sales
Charged—				
16 Mixtures	1,200	3,520	6,630	—
10 Part-spent	—	3,100	—	3,900
Totals	1,200	6,620	6,630	3,900

A second procedure is described that assumes starting with all new oxide and exposing it thrice until 63 per cent sulphur (d.b.) is reached.

The overall result is the same, but it is considered to be the worse procedure of the two. It is maintained that, for satisfactory results, blending must be carefully supervised so that homogeneous mixtures are always obtained, and that plenty of water should be employed.

Discussion

Mr. J. Hatfield (Derby) referred to Procedure "B" and asked was it not a fact that new oxide must be exposed more than the three times allowed for in the calculations.

The Author replied that this was indeed true. In practice, something of the order of six exposures were required at

Litchurch to raise new oxide to 63 per cent sulphur (d.b.). About 26 tower changes are carried out each year for the equivalent of four tower changes of new oxide during the same period. This gives 6·5 exposures.

Mr. D. Summerfield (Derby) noted that after one exposure the part-spent oxide produced was returned to the system with 55·9 per cent sulphur (d.b.). He considered this to be a very high figure, and asked how such an oxide could be active enough to gain the sulphur tonnage necessary to reach 63 per cent sulphur (d.b.).

The Author said that several factors contributed to the successful use of such material. Firstly, the original new oxide used was made to the Board's own specification and was regarded as the best at present available for towers. Secondly, the oxide was copiously wetted to raise the moisture content to the maximum. In the third place, the oxide was thoroughly mixed, resulting in a complete homogeneous charge. With 28 parallel layers in the towers, it could be seen that differences in the constitution of the layers could lead to inefficient working. So many layers in parallel was the major source of weakness of this type of purifier. Lastly, the pH of the oxide is raised to about 9·0, using sodium carbonate.

Mr. G. Cope (Walsall) asked how mixing was carried out at Litchurch.

The Author said that the constituents of the charge being prepared were fed into the boot of a belt elevator, resulting in a conical heap of oxide, sufficient for a complete charge, being accumulated. There was a large water spray discharging onto the oxide, as it left the elevator, while the charge was being built up. The heap of material was re-elevated once more at least and, time permitting, twice, water being added until the oxide was saturated.

Mr. G. F. Cole (Wellington) asked how one decided what the sulphur content would be when the moisture content was 19·7 per cent.

The Author replied that as sulphur was added to a given type of new oxide, moisture absorption capacity decreased due to the decrease in the relative quantity of lightening material present, coupled with, in practice, a decrease in surface area as particle size increased. There would undoubtedly be a simple relationship between sulphur content and maximum moisture content, at any works, depending upon local conditions and the new oxide employed.

Mr. J. M. Brown (Birmingham) said that in his paper Mr. Valle had reduced the whole question of purification to a mathematical science. He had himself had much experience in this field, and had found there was still more to learn. He could not agree with the Author's contention regarding the 28 layers, and said the main source of weakness in any scheme of purification was the question of moisture, since the oxide dries out very quickly. Mr. Valle had said that it had been found most satisfactory to rotate the towers every 6 h; he could not see why this should be so, and asked why not every 8 or 4 h? His own experience was that a 4-h interval was most satisfactory; a shorter period was not practicable without mechanization. No reference, said Mr. Brown, had been made by Mr. Valle to the volume of gas passed through the towers. His own experience had shown that a tower had a working life of 900-1,000 mill. ft³ of gas passed before moisture losses rendered the tower inactive.

The Author agreed that there were many other factors that could be sources of weakness in oxide purification besides numerous oxide layers in parallel. He said, however, that, other things being equal, it was a fact that a given volume of oxide presented to the gas as a deep layer worked more efficiently than if it were offered as a shallow layer. He did not admit saying that 6-h rotation was best; it was the frequency that had proved suitable from the "labour used in the rotation operation" point of view. There was no need, from the purification point of view, to change from regular 24-h rotation practice, but they were at Litchurch interested to see what results could be obtained, and 6-h rotation seemed a reasonable frequency to adopt. The frequency might well be changed under altered conditions of operation.

No reference had been made in the paper to gas volumes passed through a tower during its useful life, because a statement of volume alone, without reference to the hydrogen sulphide content of the gas and the rate of throughput (contact-time), was not a parameter from which comparisons could be drawn.

If a tower, capable of absorbing usefully 60 tons of sulphur, were considered, operating on gas containing 7·0 gr of hydrogen sulphide/ft³ it could be shown that it would completely purify 143 mill. ft³ of such gas. If it were one of a four-tower set, then 4 × 143 = 572 mill. ft³ would pass through the tower during the course of an exposure. In an eight-tower set, exactly twice as much would have to be passed, 1,144 mill. ft³.

Compared with a tower capable of absorbing 84 tons of sulphur from 5·0 gr of hydrogen sulphide/ft³ gas, the figures are:—four-tower set, 1,120 mill. ft³; eight-tower set, 2,240 mill. ft³.

The volume of gas purified by a vessel, expressed as the quantity of gas passed through that vessel, is a function of the number of the vessel in the series, the hydrogen sulphide content of the gas, and the useful tonnage of sulphur a vessel can absorb.

It is not relevant to make comparisons on a basis of gas volume alone. It was decided at Litchurch to discard other methods of defining a tower's "age", and the interval between changes, in favour of the basic concept of sulphur tonnage.

Mr. S. Brockbank (Newcastle-under-Lyme) asked if the installation at Litchurch was working at its rated capacity.

The Author replied that the rated capacity, 12 mill. ft³/d per set of six towers of gas containing 8+ gr of hydrogen sulphide/ft³ was normally reached only during the winter months. Carburetted water gas was purified also in the towers, admixed with the coal gas, when flows of 15 mill. ft³ at a hydrogen sulphide concentration of 6+ gr/ft³ were realized per day. During the summer, loads were about 60 to 70 per cent of winter rate.

Due to rearrangements of the towers, consequent upon the installation of a catalytic organic sulphur conversion plant, the coal gas was now purified in two sets of four towers. These handled 9 to 10 mill. ft³/d per set in winter, and 6 to 7 mill. ft³/d in summer.

In terms of sulphur tonnage, the winter production rate is about 50 tons/week, and in summer about 30 to 40 tons/week.

Mr. G. Cope (Walsall) referred to the 26 tower changes per year, and asked what the interval was between changes, and were these performed at regular intervals.

The **Author** said that at the winter rate of sulphur production, 50 tons in seven days, towers had to be changed at 11 to 12-d intervals [7 (86/50) = 12]. In the summer, when loads were lower, the intervals were proportionally longer.

Mr. F. Grocott (Solihull) said that Mr. Valle had asserted that there was a linear relationship between the sulphur content (wet basis) of the ingoing oxide and its maximum moisture content, and he asked what was meant by "maximum moisture content."

The **Author** said that the linear relationship applied to Litchurch, if not elsewhere. The maximum moisture content occurred at the point when water ran from the base of the prepared oxide heaps and dripped from freshly filled containers.

Mr. J. R. Kilvert (Birmingham) asked what was the ammonia content of the gas passing into the Litchurch towers, and what operating temperatures were experienced.

The **Author** answered that no more than 2·0 gr of ammonia/100 ft³ were allowed forward from the washers, and the figure aimed for was 0·5 to 1·0 gr. He was not convinced that ammonia was in fact necessary at all. At one time, 5 to 7 gr were allowed forward, and giving off of hydrogen sulphide resulted.

The outlet tower gas temperature ran at 25° to 35°C during the winter, but during the summer 35° to 45°C was not unusual. Tests on oxide-bed temperatures showed that the mass might reach 50° to 60°C. Encircling water sprays enabled a film of water to be kept on the tower shell during hot, sunny weather.

Mr. J. A. P. Lloyd (Northampton) asked what method of sampling the spent charges was used.

The **Author** said that outcoming charges, whether spent for sales or part-spent for stock, were not sampled at all. Sampling was unnecessary, as the calculations were accurate enough to be relied upon to within 1 to 2 per cent. As the sales oxide was over 57 to 58 per cent (w.b.), this degree of accuracy was quite adequate.

Great stress was, however, laid upon the sampling of the ingoing oxide, so that the calculations were based upon a reliable analysis. Oxide was moved from the preparation site to the container-filling site by lorry, some 70 loads being involved. An increment was taken from each load to make the sample.

Using the methods shown in the paper, it was known that a tower of part-spent oxide put in to mature for sale would indeed be saleable, if it did no more than dry out!

"The Use of Corrugated Sheeting on a Gas Works", *by K. J. Crane, M.I.Gas E., M.Inst.F.,*

Deputy Engineer and Works Manager, Swan Village Works, Birmingham Division, West Midlands Gas Board.

Paper delivered in Birmingham on 7th March, 1961.

The paper surveys the various types of corrugated sheeting frequently selected for roofing and side cladding, and discusses their suitability, fixing and maintenance under gas works conditions.

The profiles and finishes available for protected metal, and the methods of manufacture are described. The special precautions necessary to prevent corrosion of the steel core when sulphurous fumes, coke or oxide dust are present, are discussed, and proper fixing and a regular follow-up emerge as the most important factors that determine the eventual life of the sheet.

There is, says the paper, a tendency to disregard some of the commendable properties of asbestos cement, because of the special precautions, involving extra care and expense, when inspection and repairs are carried out. The solution is to choose a fixing device that will have a life equal to that of the sheet, say, 25 years, under the severest conditions, and P.V.C.-covered aluminium hook bolts are quoted as a possible choice. From the safety angle, the wisdom of using hook bolts for the fixing of side cladding is questioned, and a purpose-made rail is suggested as an improvement.

In the case of aluminium, emphasis is placed upon the necessity to adhere strictly to the instructions contained in B.S. Code of Practice 143, in order to avoid perforation of the sheets from galvanic action where they are in contact with metals of appreciably different electro-chemical potential, e.g., steel purlins, especially in such buildings as the retort house, or coke-screening plant. The precautions taken at Swan Village, based upon C.P.143, are listed.

It is considered that galvanized steel sheeting used on a gas works must be painted to obtain a reasonable life, and the initial saving, when compared with other sheets, is expended within six to 10 years.

Reference to translucent sheeting is mainly concerned with its thermal expansion compared with steel or aluminium, and the need to make provision for it when fixing.

In conclusion, the Author considers that the choice of roofing and cladding materials deserves far more consideration than it is usually given, and that more thought still should be given to the method of fixing.

Discussion

Mr. R. N. Hateley (Birmingham) said that Mr. Crane had presented a very practical Paper, summarizing the various types of corrugated sheeting used on a gas works, which should be a very useful reference to all gas engineers. He had also emphasized the need to ensure proper fixing of all types of sheeting, and for asbestos cement sheeting had recommended the use of P.V.C.-covered aluminium hook bolts. Mr. Hateley enquired how the cost of such bolts compared with that of ordinary galvanized steel hook bolts. He agreed that from his own experience, aluminium sheeting was liable to corrosion in a very short time. Mr. Hateley enquired also if Mr. Crane could give an indication of the method of protecting the bolt holes in protected metal sheeting against corrosion.

The **Author** replied that the P.V.C.-covered aluminium hook bolts were approximately three times the cost of the ordinary type of galvanized steel hook bolt. The protection of the steel core of a protected metal sheet where the hole for the hook bolt had been punched, or, preferably, drilled, was by means of the special sealing mastic that the sheet manufacturers supplied. The shank of the hook bolt should be well dipped into this mastic before being pushed through the sheet. This left a deposit of mastic around the hole, which sealed the core and hole. More sealing mastic, or a fibre washer, should then be applied on the weather side, followed by the metal washer and nut. Finally, the fastening head should be brushed with the mastic.

Mr. W. E. Dobson (Birmingham) said it was essential that corrugated sheeting should be properly fixed, but, with the type of labour available at the present day, one could not always rely upon the job being well done.

He asked if Mr. Crane, with the experience he had now had, would care to say which type of sheeting he would adopt for any future job.

The **Author** said the situation and atmosphere would decide his choice. If the roof were not going to be walked upon, asbestos cement was good value for money, providing the fastenings could be relied upon to have a life equal to the sheet, say, 20 to 25 years. The comparison of protected metal with aluminium was difficult, because his experience with the latter was limited, but it could be said that, with proper fixing, the best quality protected metal undoubtedly had much in its favour.

Mr. S. Brockbank (Newcastle-under-Lyme) said that at one time it was customary to use slates for roofing and that these required little maintenance. He asked: "Why cannot more purlins be used for asbestos cement roofing?"

The **Author** replied that he did not consider more purlins to be the answer. If the roof would have to withstand foot traffic, he would use a covering other than asbestos cement.

Mr. J. R. Kilvert (Birmingham) said that translucent roofing was widely used because it admitted light, but asked for Mr. Crane's views on the best method to clean it, bearing in mind such locations as the roof of a carburetted water gas plant, where it would quickly become coated with dust, *etc.*

The **Author** said that Imperial Chemical Industries, Limited, published a leaflet giving hints on the removal of various types of deposit from acrylic sheeting.

Mr. F. J. Bengough (Birmingham) said that, despite all precautions taken in the fixing of asbestos cement roofing, this material was still liable to crack. At his own works, he would not allow this type of sheeting to be fixed unless a "packer" were used. He agreed that the taping of the top flange of the purlins was good practice, since it could not be painted.

The **Author** agreed that it was very important that asbestos cement sheeting should not be fixed too rigidly, but considered that, if the fixer knew his job, there should be no need for "packers".

Mr. Bengough replied that it was not a question of the competence of the fixer; his point was that one could not tell when to stop tightening up the fixing-bolts.

Mr. L. H. Hardy (Birmingham) asked if Mr. Crane considered it necessary to treat aluminium sheeting by "Alochrome" dipping if it was to be fixed in contact with concrete or mortar.

The **Author** agreed that during the setting period, or if subjected to frequent wetting, either concrete or mortar would affect aluminium sheeting. He recommended, therefore, the use of a bitumastic paint as a protection against alkaline attack. He had no experience of "Alochrome" dipping.

Mr. G. H. Jacques (Wolverhampton) said that asbestos sheeting should not be fixed so that four sheets met at corners, since this would quickly become a point of weakness. He said also that the joint at corners was usually done by mitring and asked if this method could be used with protected metal sheeting.

The **Author** agreed that it was inadvisable to fix sheeting so that four sheets met at corners. Protected metal sheeting could be mitred, but it was preferable to avoid the need for this because, if this type of sheeting was cut, it destroyed the protection of the steel core.

Library Accessions

The following are a few additions to the Library since the issue of the *Journal*, Vol. 1, No. 7, July, 1961:

97*th* Annual Report on Alkali, *Etc.*, Works, by the Chief Inspectors, 1960.

Association Technique de l'Industrie du Gaz en France, Congrès, 1961. Papers Presented.

British Standard 1016 : Part 16 : 1961 (Methods for the Analysis and Testing of Coal and Coke. Part 16 : Reporting of Results).

British Standard 1296 : 1961 (Specification for Butt-welded, Single Point Cutting Tools and Blanks).

British Standard 1790 : 1961 (Specification for Length Bars and Their Accessories).

British Standard 2971 : 1961 (Specification for Class II Metal-arc Welding of Steel Pipelines and Pipe Assemblies for Carrying Fluids).

British Standard 3367 : 1961 (Specification for Fire Brigade Rescue Lines).

Canadian Gas Association, Annual Report 1960.

Coal Tar Fuels. Their Production, Properties and Application, edited by W. H. Huxtable. 2nd Edition. (Association of Tar Distillers, 1961.)

81. Gasstatistik für die Bundesrepublik Deutschland und Berlin (West). Berichtsjahr, 1959. (Verband der deutschen Gas-und Wasserwerke e.V. and Deutscher Verein von Gas-und Wasserfachmännern, e.V., Frankfurt/Main.)

Gazownictwo i Technika Sanitarna w okresie 1919-1959. Oraz perspektywy ich rozwoju i postepu technicznego. (Polskie Zrzeszenie Inzynierów i Techników Sanitarnych Warsaw, 1960.)

Das Institutim Jahre 1960. (Institut für Gastechnik, Feuerungstechnik und Wasserchemie der Technischen Hochschule Karlsruhe, vormals Gasinstitut.)

8th International Gas Conference, Stockholm, 1961. Papers presented. (See p. 587.)

Penetration of Plant Roots in Pipeline Coatings Based on Asphaltic Bitumen, by J. F. Bogtstra and B. H. Wijngaard. Communication No. 2 of the Committee for Field Data on Iron Pipelines of the Institution for the Testing of Waterworks Materials, Limited, K.I.W.A. (In Dutch, with English Summary.)

U.S. Department of the Interior, Bureau of Mines :

Development and Operation of a Pilot Plant for Feeding Bituminous Coal Slurry to a Pressure Gasifier, by W. R. Huff, and L. F. Willmott. *Report of Investigations* 5719.

Extracting Tar Acid with *Mono*ethanolamine, by James A. Stuckey. *Report of Investigations* 5705.

Gas-freeing of Cargo Tanks, by Michael G. Zabetakis. *Information Circular* 7994.

Laboratory-scale Gasification of Coal-water Slurries in a Metallic Tube Coil, by J. L. Konchesky, R. F. Stewart and J. J. Sebastian. *Report of Investigations* 5704.

Work of the Singapore Improvement Trust, 1959.

General Notices

Notice of Joint Meeting

A joint meeting between the British Coke Research Association, The Coke Oven Managers' Association and The Institution of Gas Engineers will be held in the Grand Council Chamber of The Federation of British Industries, 21, Tothill Street, London, S.W.1, on Wednesday, 1st November, 1961, at 2.30 p.m. The Chairman of the joint meeting will be T. C. Battersby, Esq., M.B.E., President, The Institution of Gas Engineers. A paper entitled "Application of Hydro-refining in the Processing of Vertical Retort Tar Naphthas and Coke Oven Crude Benzoles", will be presented by Mr. J. B. Lane, Technical Managing Director, Lancashire Tar Distillers, Limited; Vice-Chairman, Port Talbot Chemical Company, Limited; Chairman, Lincolnshire Chemical Company, Limited.

A notice incorporating a reply form will be sent with a later issue of the *Journal*.

International Conference on Physics of Semi-conductors: 1962

An international conference on the Physics of Semiconductors is being organized at the University of Exeter from 16th to 20th July, 1962, under the auspices of The International Union of Pure and Applied Physics and the British National Committee for Physics. The emphasis, as in previous conferences of I.U.P.A.P. on this subject, will be on the fundamental physical properties of electronic semi-conductors.

Further details can be obtained from The Institute of Physics and The Physical Society, 47, Belgrave Square, London, S.W.1, which is arranging the conference on behalf of the above bodies.

Offers to contribute papers should be addressed to Dr. C. A. Hogarth, Brunel College of Technology, London, W.3, and abstracts are required in triplicate by 1st February, 1962.

Pressure Vessel Design

A short course of lectures on pressure vessel design is to be held in the Manchester College of Science and Technology on 12th to 15th September, 1961. The course will survey modern methods of analysis, recent knowledge of material properties and their application to pressure vessel design problems. The fee for the course will be £13 10*s*. inclusive of coffee, luncheon and afternoon tea at the College.

Further details of the course and accommodation arrangements and costs may be had on application to The Registrar, The Manchester College of Science and Technology, Sackville Street, Manchester, 1, to whom forms of application are returnable as soon as possible and in any case before 31st August, 1961.

National Inspection Conference

A National Inspection Conference is to be held at New College, Oxford, on 5th to 8th September, 1961, to discuss the function of management in relation to inspection, the economics of inspection and non-destructive testing, and the recruitment, education and training of inspection staffs. The total cost, including conference fee, accommodation and all meals in College, will be £9 10*s*. a delegate.

Further particulars and forms of application are available from the Oxford Conference Secretariat, The Institution of Engineering Inspection, 616, Grand Buildings, Trafalgar Square, London, W.C.2.

Institution Necktie

The Council of the Institution, in response to a number of requests from members, has arranged for the manufacture of an Institution tie, which will enable members readily to identify other members they meet and with whom they associate both in work and socially.

The design incorporates a motif taken from the Institution's coat of arms and consists of a crown and two crossed torches. The tie is made of silk with the motif on a blue background.

In order that the sale of the ties shall be restricted to members of the Institution they will be obtainable only from the headquarters of the Institution at 17*s*. 6*d*. each, post free. This price will enable a contribution of 5*s*. for every tie sold to be made to the Benevolent Fund of the Institution.

Orders should be accompanied by the appropriate remittance and should be addressed to the Secretary, The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1.

Library

The Library and Reading Room of the Institution are open on weekdays between 9 a.m. and 5.30 p.m. Members may borrow books by post, excepting books of reference and certain others, on application to the Secretary.

Benevolent Fund

Contributions to the Benevolent Fund of the Institution may be paid at any time to the Honorary Secretary of the Benevolent Fund, 17, Grosvenor Crescent, London, S.W.1. It is a convenience if annual contributions are made by banker's order, and it is particularly advantageous to the Fund if such contributions are made by Deed of Covenant, whereby the Fund is able to reclaim from the Inland Revenue an appropriate sum in respect of income tax paid by the contributor. Further particulars, with deed forms and banker's orders for completion, are obtainable from the Honorary Secretary of the Fund.

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Wales Gas Board, Bute Terrace, Cardiff.

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Wales Gas Board, 93, Wellington Road, Rhyl, N. Wales.

Affiliated Associations

Irish Gas Association

President : W. A. Campbell, M.I.Gas E.,
Belfast Corporation Gas Works, Ormeau Road, Belfast.

Director : N. J. Robertson, Assoc.I.Gas E.,
Alliance and Dublin Consumers' Gas Company, Dublin, Eire.

Scottish Association of Gas Managers

President : D. Beavis, M.I.Gas E.,
Scottish Gas Board, 1, Rothesay Terrace, Edinburgh.

Honorary Secretary and Treasurer : W. Kirk, M.I.Gas E.,
Kessington, 29, Union Street, Greenock.

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Chairman : T. W. Pickthall, A.M.I.Gas E.,
North Western Gas Board, Stanley Buildings, Silver Street, Bury.

Honorary Secretary : L. G. Townsend, M.Sc., M.I.Gas E.,
North Western Gas Board, Hind Street, Birkenhead, Cheshire.